EFFECT OF FINISHING &POLISHING PROCEDURES ON THE SURFACE ROUGHNESS &MICROHARDNESS OF RESIN COMPOSITE RESTORATIVE MATERIALS

(An *in-vitro* study)

BY

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سورة البقره {الايه 286}

الاهداء

أهدي ثمرة جهدي هذا الى روح قدوتي في الحياة واغلي انسان

وانسانه على قلبي ابي وامي من كانا سببا في وجودي

والى اساتذتي الأفاضل تقديرا لعطائهم وعرفانا بجهودهم

والى كل اهلي وزوجي واطفالي

رحاب محمد حمد اخليف

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Rehab Mohamed Akhlaif

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List of abbreviations

Abbreviation	Meaning
RBC	Resin based composite
F&P	Finishing and polishing
Bis-GMA	bisphenol-A-glycidyl methacrylate
UDMA	urethane dimethacrylate
Bis-EMA	ethoxylated Bisphenol-A- glycidyl methacrylate
TEGDM	Triethylene glycol dimethacrylate
PEGMA	polyethylene-A-glycidyl methacrylate
DMA	Dimethacrylate
PEX	Semi-crystalline polyceram
MPTS	3-Metakrilloxipropiltrimetoksisilan
10 MDP	10-Methacryloyloxydecyl dihydrogen phosphate
CQ	Camphor Quinone
DMPT	N,N-dimethyl-p-toluidine
LCU	Light curing unit
LED	Light-emitting diode
QTH	Quartz tungsten –halogen
Smart RBCs	Ion-releasing composite
MEP	Bis(2-meth-acrylyoxyethyl) esters of phthalic
MEL	Isophthalic
MET	Terephthalic
SOC	Aspiro-orthocarbonate
C=C	Covalent aliphatic double bonds
DIC	Digital image correlation
FEA	Finite element method
CT	Computed tomography
DC	Degree of conversion
SD	Sof-lex diamond
SEM	Scanning electron microscope
AFM	Atomic force microscopy
Ra	Surface roughness
VHN	Vickers microhardness

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EFFECT OF FINISHING & POLISHING PROCEDURES ON THE SURFACE ROUGHNESS & MICROHARDNESS OF RESIN COMPOSITE RESTORATIVE MATERIALS

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Abstract

Aim: To evaluate the effect of three different finishing and polishing (F&P) systems; Fine diamond bur, Sof-lex discs and Astropol® cups & discs on the surface roughness and microhardness of four resin composites.

Materials and Methods: A total of 160 disc-shaped specimens (10 mm x 2 mm) were prepared in metal mold using four resin composite materials and stored in distilled water at 37˚C for 24 h. The specimens were then divided into four experimental groups (n=40) according to the type of resin composite. **Group1:** Microhybrid composite (Dynamic Plus), **Group2**: Nanohybrid (Nexcomp), **Group3:** Supernano composite (ESTELITE Σ QUICK), and **Group4**: Nanoceram composite (ZENIT). For each type of resin composite the forty specimens were divided into four sub-groups (A, B, C, & D) based on the type of finishing and polishing procedure as follow; A: Sandpaper, B: Fine diamond bur C: Astropol® cups & discs (two–step) F&P system, and D: Sof-lex discs (four–step) F&P system. The surface roughness measurements were made for all resin composite specimens using USB digital surface profile gauge and data were recorded using computer software (Elcomaster 2, Elcometer Instruments). Surface Micro-hardness of the specimens was determined using Digital Display Vickers Micro-Hardness Tester. The measurements were calculated and the obtained data statistically analyzed using SPSS software. Two-way ANOVA were applied to assess significant differences among composite materials using different F&P systems. Tukey`s Post hoc test was used for pair-wise comparisons between the means.

Results: Significant differences in surface roughness and microhardness were found according to the type of F&P systems and resin composites (P<0.05). The smoothest surface value was recorded for nanoceramic composite. The highest microhardness value was obtained with microhybrid composite finished with the Soflex discs (four-step) F&P systems.

Conclusions: Based on the obtained results it can be conclude that F&P procedure greatly affect the surface roughness and microhardness of the tested resin composite materials. Nanoceram and supernano composite exhibited the lowest surface roughness values, while nanohybrid composite exhibited the highest surface roughness value among the tested composites when finished with Soflex F&P system. Microhybrid composite exhibited the highest microhardness. The smoothest surface finish was obtained when using fine diamond bur particular with supernano and nanoceramic composites. The one step procedures exhibited the best result.

Keywords: Resin composites, finishing and polishing system, surface roughness, microhardness.

Chapter 1

INTRODUCTION

1. INTRODUCTION

Resin composites become one of the most investigated material in dentistry. Patients and clinicians prefer these materials because of their excellent esthetic, moderate cost compared to ceramics and adhesion to tooth structure (Santos & Dias, 2002). With the development of composites, one of the desirable features for a satisfactory and esthetic restoration is smooth surface finish (Morgan, 2004). Finishing and polishing are measures undertaken in the restorative procedure to obtain a smooth, shiny surface of a restoration, keeping in mind esthetics and maintenance of periodontal tissues in healthy condition. Finishing procedure means a gross contouring, shaping, and smoothing to achieve an ideal anatomy, whereas polishing is a step performed after finishing to remove the roughness and scratches created by the finishing devices (Banerji & Mehta., 2017; Jefferies et al., 2007). Optimal finishing and polishing are important clinical steps in restorative dentistry that influence both esthetics and longevity of restorations (Banerji & Mehta, 2017). Improper finishing and polishing of dental restorations can result in surface roughness which is subsequently associated with excessive gingival irritation, plaque accumulation, more surface staining, and poor esthetics of restored teeth that may in turn lead to enamel demineralization, recurrent dental caries, as well as periodontal problem (Morgan, 2004). It has been documented that change of surface roughness in the order of 0.3 mm can be detected by the tip of the patient tongue that may cause problems in quality of the entire restorative work (Heintze et al., 2006).

Ideally, the finishing and polishing procedures should be delayed at least 10-15 minutes following the final phase of light curing procedure so as to permit some dark polymerization to take place (Banerji & Mehta., 2017). Delaying the time of the finishing and polishing procedures make the restoration less suscebitiple to negative effect produced by heat generation (Da Silva et al., 2010; Venturinni et at., 2006).

Microhardness is defined as resistance of the material to indentation and is an important mechanical property that predicts the polymerization degree and depth of cure of restorative materials (Santos et al., 2002). Microhardness is essential to the material in resisting masticatory forces, increase wear resistance and providing greater longevity of the restoration. When microhardness of the composite reduces, the material becomes more susceptible to scratches which cause bacterial adhesion, discoloration and failure of the restoration (Da Silva et al., 2010). Therefore, the surface microhardness of composite resin should not be changed after restoration in mouth (Morgan, 2004).

A wide variety of instruments and materials are commercially available and used by dental clinicians for finishing and polishing procedures such as abrasive systems include aluminum oxide (AL2O3), carbide compounds, diamond abrasives, silicon dioxide, zirconium oxide and zirconium silicate and polishing instruments that include coated abrasive discs and stripes, stones, aluminum oxide or diamond pasts, soft or hard rubber cups or points, and wheels or brushes impregnated with abrasive (Gulati & Heged, 2010). All these instruments and systems available as one-, two-, three- and four-step finishing and polishing system. The effectiveness of the polishing system depends on the hardness of the cutting particles and materials, and the production of smooth surface depends on the ability to cut the filler particles and organic matrix of the resin composites (Barcellos et al., 2013).

In the recent years, resin composites have rapidly evolved in terms of filler particles and resin matrix composition and structure (Francis et al., 2017). The applications of Nano, bulk-fill, fiber-reinforcement and ion-releasing technologies in the dental materials field have resulted in the development of new resin composite containing different size and shape particles (Francis et al., 2017; Garoushi et al., 2018; Lassila et al., 2019).

Several studies have been conducted to evaluate the effect of different finishing and polishing systems on different types of resin composites (Barcellos., 2013; Francis et al., 2017 ; Alfawaz , 2017; Eden et al., 2012 ; Koh et al, 2008; Ozel et al., 2008; Watanabe et al ., 2005). It has been documented that nanofilled composite showed superior polishability than the microfilled composite and Filtek Z250-hybrid composite when comparing different finishing and polishing systems. The hybrid composite showed the least polishability compared with microfilled and nanofilled composites, and the Enhance polishing system showed the least polishability among all the polishing systems used (Watanabe et al., 2005).

In addition, the Sof-Lex Pop-on system was found to produce smoother surface than Enhance polishing system (Koh & Neiva., 2008). Large particles embedded in Sof-Lex disks tend to rip through the surface of the composites and when used with certain hybrid composites tend to cut and abrade filler particles and resin matrix equally, resulting in smoother surface (Koh & Neiva., 2008). There are several methods of polishing: a single-step and a multi-step technique. Diamond materials are usually used for a single-step technique and only need one step of polishing, while a multi-step techniques uses materials (usually aluminum oxide) gradually decreasing from the most abrasive to the smoothest (Howard et al., 2010). However, some researches showed that, the polishing protocol was significant, and stronger factor than the type of composite material (Lassila et al., 2020) and reported that there is correlation between surface gloss and surface roughness. The lower surface roughness the higher surface gloss (Lassila et al., 2020; Heintze et al., 2006) and the surface gloss improved consistently during the polishing procedures (Heintze et al.,2006). Additional factors can affect the polishing results, including the amount of pressure utilized during polishing, the orientation of the abrading surface and length of time spent with each abrading surface and abrasive material (Yadav et al., 2016). The discrepancy between the size of abrasive particles present in the abrasive discs and abraded material should be minimal to reduce the creation of scratches or roughs on the polished surface (Erdemir et al., 2012).

Transparent matrices such as Mylar stripe are preferred to produce smooth surface finish with highest gloss, but it is difficult to achieve proper anatomical contour of the restoration with Mylar strip (Nair et al., 2016). In this circumstance, it has been found that the lowest surface roughness was found in the sample that in contact with matrix stripes, were lower than threshold mean roughness (Ra) value of 0.2 mm (Nair et al., 2016; Kumari et al., 2019). Furthermore, authors found that, the Soflex spiral wheel had the least roughness value, which promote homogenous abrasion of fillers and resin matrix (Kumari et al., 2019). The trend of sof-lex discs is to provide a slightly smoother surface with aluminum oxide abrasive on rigid matrix as this can flatten the filler particles and abrade the softer resin matrix at an equal rate (lainovica et al., 2013). Limited use of aluminum oxide discs is because of their shape, which makes them difficult to use efficiently, particularly in the posterior regions of the mouth. Soflex spiral wheels have unique, flexible shape which easily to adapts to irregular, convex and concave tooth surfaces and is effective from any angle. The unique shape of soflex spiral wheel is an advantage over soflex discs in adapting to tooth structure (Kumari et al., 2019).

High quality finishing and polishing of dental restorations are important aspects of clinical restorative procedures, and the ultimate goal of every dentist is to achieve smooth surface restoration in fewer steps. Therefore, this study was conducted to evaluate the influence of three different finishing & polishing procedures on the surface roughness and microhardness of four resin composite restorative materials. It is essential to determine which F&P system offer the best results. In addition, there is no certain agreement and harmony on which finishing and polishing material and technique provides the smoothest surface for resin composite, especially with the increase launch of new finishing and polishing products in the market.

Chapter 2

REVIEW OF THE LITERATURE

2.1. INTRODUCTION

The beauty of the smile is exceedingly important in the daily life. Dental aesthetics being progressively more valued. Dental professionals use composite resins as the first choice materials, because these materials have combination of optical and proper mechanical properties, similarity to the enamel and dentin, reliability and decent biomimetic replacement and ability to withstand high compressive forces in the mouth with excellent aesthetic (Mitra et al., 2003; Pratap et al., 2019; Singh et al., 2017). Beside the aesthetic appearance of composite resin, it overcomes the toxicity of the amalgam, however the composite has some weaknesses such as, poor color stability, susceptibility to wear, leakage, and polymerization shrinkage (Sang et al., 2021 ; Yori Rachmia & Fauziyah., 2019). Well-finished restoration with adhesive properties not only improves the appearance of the tooth, but it also decreases the risk of secondary caries and periodontal disease. To achieve the best results, dentist must be aware of the proper polishing method and timing for each material (Madhyastha et al., 2015).

This section reviews the following topics relevant to the study

2.2 Historical background of resin composites.

2.3 Composition of resin composites.

2.4 Light curing unit.

2.5 Classification of resin composites.

2.6 Polymerization of resin composites.

2.7 Finishing and polishing of resin composites.

2.8 Factor affecting the finishing and polishing procedure.

2.9 Surface roughness.

2.10 Microhardness.

2.11 Effect of finishing and polishing procedures on the surface roughness and microhardness of resin restorative materials.

2.2 Historical background of resin composites

Before 1940, the methacrylate based resin was utilized in denture base which cure by application of heat (Fink, 2013). Later in 1940 and early 1950, the polymethyl methacrylate resins was replaced the silicate cements with acrylic resins (Figure 2.1). The effectiveness of these acrylic resins embrace insoluble in oral fluid, resemble tooth appearance, ease of handling and inexpensive. However, this material was not achieved the demand of the ideal restorative material due to polymerization shrinkage (Ravi et al., 2013). Shrinkage of composite lead to gap formation marginal leakage and post-operative sensitivity and or secondary caries in addition, composites were suffer from poor wear resistance, high coefficient of thermal expansion and high water sorption (Riva & Rahman ., 2019). Pre-polymerized beads were later inserted into resin which reduced polymerization shrinkage to 3.5% percent, but the shrinkage associated with these methacrylate resins remained the biggest downside. Therefore, Dr Raphael Bowen mixed quartz particle with epoxy resin to combat excessive shrinkage in dental resin content. This shows promising effects in vitro but failed to cure when used clinically due to the epoxy resin's setting reaction is susceptiblity to moisture contamination. Dr. Bowen also substituted epoxy resin with methacrylate to create Bis-GMA, also known as "Bowen's Resin," which has been the most widely used resin substance since 1960 (Barszczewska-Rybarek et al., 2015).

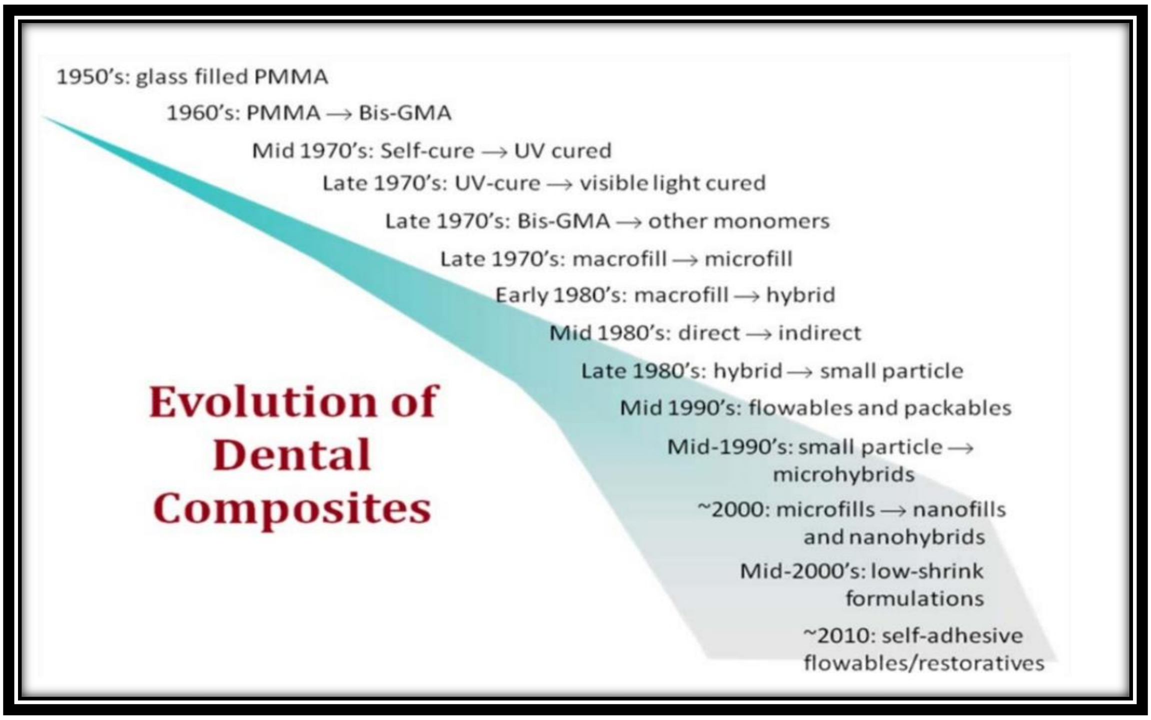

Figure 2.1 Evolution of resin composites (Jack & Ferracane, 2011).

2.3. Composition of resin composites

Dental resin composite is dental material made from synthetic resin and is defined as either purely filled resin or resin based composite (Robert et al., 2006). Synthetic resins gained popularity as restorative materials because they are insoluble, having a strong tooth-like appearance, show resistant to dehydration, simple to handle, and low cost (Robert et al., 2006). The matrix phase and reinforcement phase are typically mixed in dental resin composites. The matrix phase contains BisGMA and other dimethacrylate monomers such as TEGMA, UDMA, HDDMA (Robert et al., 2006). The reinforcement phase, composed of silica, glass, or quartz filler, comes in the form of fibers, tubes, or particles. With the aid of a coupling agent, the reinforcing phase is bonded to the matrix phase. The resin wears quickly without filler, shrinks rapidly, and is exothermic. And, in the majority of modern implementations, a photoinitiator dimethylglyoxime is often used to obtain specific physical properties, such as flowability. Formulating particular concentrations of each constituent allows for much more tailoring of physical properties (Anusavice et al., 2013; Ravi et al., 2013).

I. Resin matrix:

A dental composite made primarily of a resin-based oligomer matrix including bisphenol A-glycidyl methacrylate (BisGMA), urethane dimethacrylate (UDMA), or semi-crystalline polyceram (PEX) (Anusavice & Philips., 2004). Additionally, Bis-GMA has a higher viscosity, which makes it more difficult to handle and results in a lower degree of monomer conversion (Peutzfeldt, 1997). Bis-GMA has some advantages over other small-sized dental monomers like methyl methacrylate, including less shrinkage, higher modulus, and lower toxicity due to its lower instability and diffusivity into tissues (Sideridou et al., 2002). However, Bis-GMA must be thinned with more stable dimethacrylate monomers, such as tri-ethylene glycol dimethacrylate (TEGDM), to cope with its high viscosity (Kumar et al., 2016). BisGMA has a higher refractive index than other monomers, making it a good substitute for dental composites (Pratap et al., 2019).

A new form of methacrylate monomer was launched in 2018 to regulate the volumetric shrinkage and polymerization stress of resin composite. Increasing the distance between methacrylate groups was conducted to reduce the density of cross bond. Another approach was increasing monomer rigidity (Riva & Rahman ., 2019). Some examples of low shrink methacrylate monomers are dimer acid, DuPont monomer, and FIT-852 (Manojlovic et al., 2016).

Silorane, is a new monomer system was designed to mitigate shrinkage and internal stress caused by polymerization. Silorane is derived from the words siloxane and oxirane (also known as epoxy). The functions of siloxane and oxinrane are to give resin composite hydrophobic properties and to open ring cross bonds through cationic polymerization, respectively. For silorane polymerization, a specific initiator system is needed (Riva & Rahman ., 2019).

II. Filler:

Different translucent mineral fillers are used to stabilize resin composite and reduce shrinkage and thermal expansion during the curing process. Generally, the filler content in most resin composites ranges from 30% to 70% by volume and 50% to 85% by weight (Garoushi et al., 2018). The inorganic fillers can increase the composite's hardness, wear tolerance, and translucency by incorporating silicon dioxide (silica), quartz, other glass powders, ceramic fillers (Xinxuan Zhou et al., 2019). The type of inorganic filler particles and the ratio between the filler particles and the organic matrix directly influences the ability of composite resin to withstand wear and stress behavior. There are essentially two types of filler particles: microfil particles and macrofil particles while a mixture of microfil and macrofil particles are termed hybrid (Roeters et al., 2005). The material properties are mostly determined by the stable boned between the filler and the matrix. The abrasion resistance of the restorative substance is also influenced by the quality of the bond (MANHART et al., 2000). Furthermore, the radiopacity is specifically influenced by the form of filler, which is usually obtained by using high-atomic-number elements like Barium and Strontium in filler particles to improve radiopacity (Kruzic et al., 2018).

III. Coupling agents:

Previous composites lacked adequate bonding between the reinforcing phase and matrix phases, causing mechanical properties to deteriorate over time. Proper bonding between the resin matrix and the filler, as a function of the coupling agent, can strengthen the physical and mechanical properties (Kruzic et al., 2018; Yori Rachmia & Fauziyah., 2019). The silicon organic compound is the most popular used coupling agent named as, silane coupling agent, 3-metakrilloxipropiltrimetoksisilan (MPTS) (Riva & Rahman ., 2019). Thus, organic silanes, such as 3-methacryloxypropyltrimethoxysilane and 10-methacryloyloxydecyl dihydrogen phosphate (10MDP), are commonly used as coupling agents because their chemical functional groups can enhance the bond strength between the reinforcing filler and the resin matrix (Xinxuan Zhou et al., 2019).

IV. Initiators/activator systems:

Around 1975, resin composites were cured using the photo polymerization process. The photo polymerization mechanism begins with the use of a photo-initiator and an electron donor or tertiary amine in a photo-initiation process. The most widely used photo initiator is yellow powder camphor Quinone (CQ), with electron donor in conjunction with tertiary amines DMAEMA and EDMAB as a co initiator. Because of its wide absorbance spectrum to visible light which range from 360–510 nm with peak absorbance at 468 nm, CQ is favored as a photo-initiator (Pratap & Gupta et al., 2019). Amines are used as co-initiators or accelerators in order to speed up the polymerization process by transferring protons and electrons via initiating radicals. N, N-dimethyl-p-toluidine (DMPT) is one of the most commonly used co-initiators, but it is toxic due to its low molecular mass (Dunnick et al., 2014). The chemical cure resin composes of two pastes. The first paste contains benzoyl peroxide as an initiating material, while the second paste contains a tertiary amine activator (Santini et al., 2013).

V. Pigment or coloring agents:

Colorants like metallic oxide, stabilizer system, curing-promoting agents like catalyst, and so forth auxiliary have enhancement color effects. Catalyst is added to control the polymerization speed. Other constituents such as dimethylglyoxime can also be used to improve certain physical properties such as flowability (Xinxuan Zhou et al., 2019).

2.4. Light curing unit

Currently, the most reliable types of LCU are the LED (light-emitting diode) units, but even these can vary considerably in their light output (irradiance) and they can deliver very different emission spectra (Rueggeberg., 2011). There is also considerable variation in the chemical formulation, shades, filler types, and light-transmission characteristics of resin composite (Shortall., 2005; Price et al., 2010; Satterthwaite et al., 2009).

Unfortunately, many dental resin composite manufacturers do not indicate what specific wavelengths are required for optimal polymerization of their materials. General statements, such as the LCU should “deliver light in the 400 to 500 nm range of wavelengths,” are not sufficiently specific because even small differences in the spectral emission from LCUs can affect their ability to polymerize resin composites (Rueggeberg., 2011; Leprince et al., 2010; Price et al., 2010).

If the LCU is a quartz tungsten-halogen unit (QTH), the range of wavelengths is sufficiently broad to adequately polymerize any dental resin composites material. However, most LED or laser LCUs produce a very narrow spectral emission and are usually optimized to cure the commonly used camphorquinone photoinitiator that is most reactive to light at ~468nm (Rueggeberg., 2011). Broadband LED units have been introduced that use two or more different colors of LED, meaning that their spectral output includes both blue (~460nm) and violet wavelengths (~410nm) of light. These broadband "polywave" LED units are designed for polymerizing resin composites containing both conventional and alternative photoinitiators (Leprince et al., 2010; Palin et al., 2008; Price & Felix., 2009). If the dentist is using resin composites that does not include these alternative photoinitiator, a broadband LED unit is not needed, because light emitted at these lower wavelengths is less efficient in polymerizing resins that use camphorquinone.

Concepts of photocuring actually underwent a one hundred and eighty degree turn, because of these issues, and QTH units became available with "soft start" features. The idea here was to try and slow the rate of polymer curing, and allow some flow of the unbonded restoration surfaces that would relieve the internal stresses within the restoration. Many types of soft start features termed the "step" and "ramp" modes were incorporated, where initial levels of light during an exposure were either a continuous low value for a short time, after which full output was applied, or the initial phase of the exposure applied a time-based, increase in intensity, until full value was reached, after which that value was held until the light shot off. One additional option included a distinct time delay (from 5 to 10 minutes) between initial application of a low intensity, short duration exposure (200 mW/cm2 for 3 seconds), and subsequent application of full light output for a longer time (500 mW/cm2 for 30 seconds): the "pulse-delay" technique (Yap et al., 2002).

2.5 Classification of resin composites

Various classifications of the resin composites have been developed based on different techniques to simplify their identifications and uses (Zhou et al., 2019). Composites are categorized in general based on the components, quantities, and properties of their filler or matrix phases, as well as their handling characteristics. Filler content (weight or volume percent), filler particle size, and method of filler addition are the most common classification methods. The matrix composition may also be used to describe composites (Zhou et al., 2019).

Based on the filler particle size, Lutz and Phillips (1983) developed a classification for composite resin that is still applicable today, dividing composites into macro filler composites, microfiller composites, and hybrid composites. Recently, Zhou et al., 2019 proposed a four-category grouping of dental composites based on their various structures and performance characteristics as follow:

1. Filler Particle Size: macrofilled, microfilled, hybrid, new hybrid, and nanohybrid are the different types of filler particles.
2. Chemically activated, light activated, heat curd, and dual-cured are the different types of curing modes.
3. Divided into direct and indirect categories, depending on the restorative method.
4. Packable, flowable, polyacid adjusted, self-adhesive, osmotic, and eventually Bulk-fill, according to clinical use.

The most common classification method of resin composite materials is based on filler content and size. Composites can be categorized into macrofilled, microfilled, hybrid, new hybrids, and nanofilled composites, according to Lutz and Phillips' classification systems from 1983 as follow:

I. Macrofilled (conventional) composites:

Macrofilled resin composite are considered the first generation of composites, since they contain comparatively large filler particle sizes (macrofiller) ranging from 10 to 100 mm of ground quartz with a high filler loading of around (55–65 percent volume). They were produced in the late 1970s (Willems et al., 1992; Riva & Rahman., 2019). Conventional macrofilled composites with filler particle sizes ranging from about 10 to 50mm are mechanically hard, but difficult to polish and color match (Zhou et al., 2019).

Macrofilled composite had a number of drawbacks, including a lack of wear resistance and a high surface roughness that made them more vulnerable to staining and plaque deposition (Willems et al., 1992). As a result, experts devised lighter, rounded fillers with a suitable particle size distribution in order to prevent the above issues (Lu et al., 2006).

II. Microfilled composite:

In the late 1970, microfilled composite resin was produced (Riva &Rahman., 2019). They were generated between 1970 and the early 1980s, to improve poor properties of the conventional types (Lu H et al., 2006). This resin has particle size between 0.04-0.2 mm with filler filling of 30 percent weight (wt). Pre-polymerized resin was grinded with colloidal silica particles and mixed with resin matrix and micro-sized filler particle to improve filler filling up to 30-50 percent wt (Riva &Rahman., 2019). However, another auothers found amorphous spherical silica with a diameter of microfilled 40–50 nm, which became more esthetic but they were more born to fractures and anatomical shape degradation due to wear. The particle size was chosen to solve the critical problem of long-term esthetics and mechanical properties (Zhou et al., 2019).

In comparison to other composite resins, microfilled composite resin has a high polishability (Anusavice et al., 2013). In the microfilled composite resin, increasing the filler filling decreases the polymerization effect. Because of the weak bond between the composite particle and the matrix, this composite resin cannot be used as a stress-bearing surface restoration material (Anusavice et al., 2013). Therefore, microfilled composite are mostly used in class III, class V, and narrow class I restorations due to their inferior mechanical properties as compared to hybrid composite (Lu et al., 2006).

III. Hybrid composites:

The particle size of traditional composites was reduced to create hybrid composites, which resolved the significant problem of long-term esthetics and mechanical properties. Hybrid composites are one of the best restorations for posterior teeth (Zhou et al., 2019). Barium glass, with an average particle size of 0.5 to 1.0 microns, is the most popular filler today. To enhance handling properties and reduce stickiness, a small amount of micro-filler is applied (Ravi et al., 2013). Additionally, with less than a few micrometers of glass filler particles and small quantities of colloidal silica particles (10–

50 m and 10–50 nm), the latest generation of hybrid composites has lower shrinkage, improved polishing efficiency, and improved esthetics (Zhou et al., 2019).

IV. Packable composites:

Packable composite is a type of dental resin composite that is commonly used as a replacement for amalgam in posterior restorations. Packable composites, which were first used in the late 1990s, are stiffer and less sticky than traditional composites (Zhou et al., 2019). This material has a greater tendency to shape and work better than traditional composites. They have good proximal contact points when packed or pushed by an instrument. However, several studies have shown that their mechanical and physical properties are little better than those of standard composites (Zhou et al., 2019).

V. Flowable composites:

Flowable Composites are a type of composite material that can flow. Since their introduction in dentistry in 1996, flowable composites have drawn a lot of interest (Zhou et al., 2019). They are traditional composites with filler loading reduced from 50–70% to 37–53% (by volume) (Baroudi & Rodrigues., 2015).

Since the viscosity is reduced and the flowability is improved, flowable composites may be injected through tiny cracks or corners of a cavity with an injection syringe, simplifying the handling process and reducing the time spent in the clinic (Baroudi & Rodrigues., 2015). However, they have a high wettability of the tooth surface, allowing penetration into any irregularity; and the ability to shape thin layers, reducing or avoiding air inclusion or entrapment (Roggendorf et al., 2011). Moreover, since shrinkage is one of the main material properties related to clinical applications, flowable composites demonstrated higher shrinkage than typical non-flowable composites (Roggendorf et al., 2011). Newer generation flowable composites have a broader variety of uses, including preventative resin restorations, minimally invasive Class II restorations, Class V abfraction lesions, and so on, thanks to advancements in resin matrix and filler systems (Roggendorf et al., 2011). The flowable composites are only recommended for low stress bearing areas restorations, not for posterior restorations on occlusal surfaces, due to the lower filler content and reduced physical properties and wear resistance. Studies on the flexural strength, wear, and other mechanical properties of flowable composites have concluded that they have weaker mechanical strength than traditional resin composites (Zhou et al., 2019).

VI. Nano filled composite:

Nanotechnology was first used in dentistry in 1997, and it has since opened up new possibilities for the creation of better restorative products. Nanotechnology can improve the polishing ability and therapeutic success of restorative materials by using finer filler particles (Didem et al., 2016).
Because of the advances in nanotechnology resin composite with nanoparticles of 25 nm and agglomerate nanoparticles of 75 nm is now available (Riva &Rahman., 2019). The filler packing of composite resin is increased by 79.5 percent using zirconium/silica and nanosilica particle with agglomerate nanoparticle. The lower dimension and area distribution of filler particles cause an increase in filler filling. Increased filler filling reduces polymerization shrinkage and improves composite resin mechanical properties (Riva &Rahman., 2019).

The use of nano, bulk-fill, fiber-reinforcement, and ion-releasing technology in the field of dental materials has resulted in the production of modern resin composites with a variety of particle sizes and shapes. These materials include a variety of volume fractions of filler particles ranging in size from micrometers to nanometers (Lassila et al., 2020). Moreover, these products, according to the manufacturers, have enhanced handling properties, sufficient strength, and a high gloss ceramic-like polished surface that mirrors natural enamel and dentin (Lassila et al., 2020). With this technology, filler particles account for 80 percent of the resin matrix in total weight (Atabek et al., 2016). According to the manufacturers, combining nano-sized particles and nanocluster compositions decreases the interstitial spacing of the filler filling, resulting in increased physical properties and polish retention (Atabek et al., 2016).

VII. Nano-ceramic composite:

Nano-ceramic processing was developed in 2003 by combining nanotechnology with methacrylate-modified polysiloxane. Glass fillers ranging in size from 1.1 to 1.5mm made up 76 percent of the overall weight of the nano ceramic composite resins (Atabek et al., 2016). Hence, Nano-ceramic manufacturing, according to the manufacturer, has superior esthetics and handling properties. It is well established that the esthetic properties and polishing ability of a substance increase as the size of filler particles is reduced and the percentage by weight is raised (Da Costa et al., 2007).

VIII. Bulk Fill Resin Composites:

Bulk fill resin composites: Traditionally, each layer of dental resin composite can be cured individually, with each layer being less than 2 mm thick. Bulk-fill composites were created to speed up the time-consuming process of gradual cavity filling (Zhou et al., 2019). Due to high color translucency of these materials raising the depth of cure and more advanced initiator method shortening the light-curing time, the newly bulk-fill composites, which enable incremental filling of up to 4 mm in thickness, have been shown to ensure maximum polymerization at this depth (Zhou et al., 2019).

X. Short fiber reinforced composite:

Short fiber bonded composite resin is used as one of dental restorative materials. Adding 5 % -7.5 % of short fiber filler into filler particles composite resin with filler filling of 60 percent wt. This filler decreases polymerization shrinkage by 70% and improves the physical properties of composite resin, such as flexural resistance, modulus of elasticity and toughness fracture (Riva &Rahman., 2019). Moreover, in the operation of posterior dental restorations, filler short fiber often increases stress bearing (Kruzic et al., 2018). Glass fiber is the most widely used short fiber reinforced form. Polyvinyl acetate, polyethylene, and aramid fibers, as well as nylon fibers, have all been formed as composite resin fillers (Riva &Rahman., 2019).

XI. Ion-releasing composite (smart RBCs):

In 1998, an ion-releasing composite was introduced (Ariston PHc, Ivoclar Vivdent, Schaan, Liechtenstein). Depending on the PH value directly next to the restorative material, this composite material emits fluoride, hydroxyl, and calcium ions (Fink., 2013). The release rate of functional ions increases with declining pH value due to active microorganisms in dental plaque, and vice versa. This phenomenon is focused on a recently developed alkaline glass filler that is supposed to minimize secondary caries formation at restoration margins by inhibiting bacterial development, reducing demineralization, and buffering acids formed by cariogenic microorganisms (Fink, 2013).

XII. Low shrinkage composite:

For the purpose of minimizing polymerization shrinkage and related stresses in composites, a variety of materials have been produced, tested, and tried (Malhotra et al., 2011). The introduction of eutectic monomer systems such as bis (2-meth-acrylyoxyethyl) esters of phthalic (MEP), isophthalic (MEL), and terephthalic acids (MET) and the use of liquid crystalline monomers that shrink less when photocured were among the earlier developments. Moreover, Aspiro-orthocarbonate (SOC) is a bicyclic ring-opening monomer that exhibits homopolymerization through double spiro-acrylic ring opening, resulting in no shrinkage or even expansion during polymerization (Malhotra et al., 2011).

2.6. Drawbacks of resin composite

However, resin composites have a number of disadvantages: Despite the cosmetic advantages of resin composite over amalgam, one of the drawbacks of resin composite is shrinkage from polymerization, which is influenced by volumetric shrinkage and viscoelastic activity, among other factors (Lamberchts et al., 2006). As a covalent bond is formed between monomers, volumetric shrinkage corresponds to the reduced distance between two groups of atoms as well as the decrease in free volume (Braga et al., 2005). Furthermore, if there is heavy wear from chewing and grinding composites have a habit of to wear out faster than metal fillings. Composites also should be adequately isolated when a dental composite is placed as it reflected high technique sensitivity to the tooth (Kidd et al., 2009). It has been reported that successful outcomes in direct composite fillings is related to the skills of the practitioner and technique of placement**.** An additional main disadvantage of resin composite restorations is their affinity to be discolored over time by colorants in food and beverages (Heintze et al., 2012).

2.7. Polymerization of resin composites

The term "polymerization" refers to the process of transforming a resin-based composite (RBC) from a plastic to a semisolid state, in which the monomer is transformed into a polymer. This process is divided into four stages: activation, initiation, propagation, and termination (Rueggeberg., 2011).

The activation of a light cure composite resin occurs when camphorquinone, the photo initiator mechanism, is triggered by blue light and chemically converts into an excited triplet state, and then interacts with the tertiary amine in the presence of an accelerator to create further free radicals. This free radical react with monomer molecules to form polymerization active centers. Monomers are sequentially attached to the active centers in the propagation step, forming the beginning of long cross-linking polymer chains that bring them closer together to form covalent bonds (Rueggeberg., 2011). During polymerization of composites monomer approximates to form polymeric chain formation this resulted in shrinkage stress which is an intrinsic mechanism of chemical and light composite resin activation (Watts et al., 2003).

Many resin composite polymerization reactions result in the rupture of covalent aliphatic double bonds C=C in reacting monomers and the forming of single covalent bonds C–C. This is usually followed by a 0.3–0.4 nm shrinkage of the intermolecular distances between polymer chains (Lia Mondelli et al., 2016). The resin composite and cavity walls, as well as the interface between them, experience pressures and strains as a result of shrinkage (Truffier-BOUTRY et al., 2006).

Several methods for measuring polymerization shrinkage have been developed, including digital image correlation (DIC), the finite element method (FEA), and the fiber optic method (Riva &Rahman., 2019). In addition to micro-computed tomography

(CT), or can be calculated indirectly using volumetric/linear shrinkage and cuspal deflections, or it can be estimated indirectly using marginal leakage analysis (Kamalak et al., 2018).

The polymerization contraction and shrinkage stress of dental restorative products can be influenced by a number of factors. One of the factors that influences polymerization shrinkage is the resin matrix structure of a restorative material. TEGDM, which has a higher shrinkage than other resins, is used in the resin matrix of nanocomposite and nanohybrid composite samples. The estimated shrinkage for TEGDM is approximately 12.5 percent, while the value for BisGMA is 5.2 percent, and the shrinkage for standard resins is between 2 and 3 percent (Karimzadeh et al., 2016).

A restoration that has not been sufficiently polymerized may have a smoother surface that retains the scratches caused by the finishing procedures. These scratches will weaken the restoration's fatigue strength, causing it to premature failure (Yazici et al., 2010).

It has been documented that restoration placement techniques are widely recognized as a major factor in the modification of shrinkage stress. By using specific restorative techniques stress resulting from constrained shrinkage may be reduced. Applying the composite in layers instead of using a bulk technique is suggested to reduce shrinkage stress (Donly & Jensen.,1986). Three main factors concur to reduce shrinkage stress: use of a small volume of material, a lower cavity configuration factor, and minimal contact with the opposing cavity walls during polymerization (Donly& Jensen.,1986).

Since the intensity of the curing light is high at the surface and decreases as it penetrates deeper into the composite, the layer thickness has an influence on the degree of conversion of the light-curing composite. When the composite is applied as a single layer, the polymerization of light-curing composites does not induce stress at the bottom of relatively deep cavities due to the low degree of polymerization. On the other hand, stress in self-curing composite would be equally generated within the cavity. In a shallower cavity the maximum polymerization would take place in the light-curing composite throughout the cavity in the same manner as in the self-curing composite, since light would instantly penetrate the composite and there would be a slight reduction of light intensity throughout the material (Kinomoto et al., 1999).

It has been shown that high intensity lights may provide higher values for degrees of conversion (DC) and physical properties (Rueggeberg et al.,1994). although they also produce higher contraction strain rates during composite polymerization (Sakaguchi et al., 1997).

A slower curing process may allow stress relaxation to take place during the polymerization process. A recent approach designed to allow the resin composite some freedom of movement. It consists of an initially reduced conversion degree of the resin material. Because the polymerization process is dependent on total light energy rather than light intensity alone, two different approaches can be proposed: the application of a lower intensity light for a longer period of time or use of variable intensities over a given period of time. An equivalent degree of conversion may be achieved with both techniques (Miyazaki et al., 1996). These techniques initially use low-intensity curing for a short period of time in order to provide sufficient network formation on the composite surface while delaying the gel point in the lower layers until a final high-intensity polymerization is initiated. Excellent marginal sealing and cavity adaptation can be achieved with this method (Mehl et al., 1997).

2.8. Finishing and polishing procedures of resin composites:

An effective composite restoration requires not only careful selection of restorative materials with ideal esthetics and mechanical properties, but also careful consideration of the finishing and polishing protocol (Kumari et al., 2019).

The finishing procedures is defined as contouring or reducing the restoration to obtain the ideal anatomy through re-establishing occlusal morphology and a tight tooth-to-restoration margin to achieve optimal function (Kumari et al., 2019). The polishing procedures involves reducing and smoothing the roughness and surface scratches created by finishing instruments (Kumari et al., 2019).

Finishing and polishing are critical steps in ensuring the restoration's lifespan. Both phases can be done directly after the resin composite's final polymerization, which is the most frequent step in clinical practice, or they can be done later (Ergücü & Turkun., 2007). Ideally the finishing and polishing procedures should be delayed at least 10-15 minutes following the final phase of light curing procedure so as to permit some dark polymerization to take place (Banerji & Mehta., 2017). Delaying the time of the finishing and polishing procedures make the restoration less suscebitiple to negative effect produced by heat generation (Barcellos & Borges.,2013; Gulati & Heged., 2010). The finishing and polishing technique includes preparing the surface of the restorative substance in order to achieve a surface that is equivalent to enamel. The aim of this procedure is to reduce plaque accumulation and therefor prevent development of secondary caries. Furthermore, since the tongue can detect even the tiniest variations in surface roughness, down to about 0.3 m, having a very smooth surface is important otherwise resin composite can cause problem in the quality of the dentist work (Ergücü & Turkun., 2007; Da silva et al., 2010). Improper finishing and polishing of dental restorations can result in surface roughness which is subsequently associated with excessive gingival irritation, plaque accumulation, more surface staining, and poor esthetics of restored teeth that may in turn lead to enamel demineralization, recurrent dental caries, as well as periodontal problem (Morgan ., 2004).

Smooth, highly polished composite restorations are aesthetically appealing, allow for maintenance oral hygiene, and are more long-lasting than rough restorations due to less biofilm forming (Sabbagh et al., 2004). Finishing and polishing is an important step in restorative dentistry that the rough surface have an effect on the wear properties and marginal integrity of posterior composite resin restorations (Aljamhan et al., 2021).

The general effect of a finishing and polishing system on surface roughness is largely dependent on both the polishing system and the restorative material (Babina et al., 2020). Therefore, the resin matrix, as well as the size, form, and filling of the fillers, influence the polishability of composite. Resin matrix and filler particles present different hardness values. During finishing–polishing procedures, if the fillers are significantly harder than the resin matrix, the matrix will be abraded away first, and the filler particles will be left at the surface, increasing the aggregate surface roughness (Ehrmann et al., 2019). Thus, the type of composite material used, as well as the finishing and polishing systems used, are critical in achieving a smooth surface that prevents the onset of subclinical or even clinical inflammation (Kumari et al., 2019).

2.8.1 Types of finishing and polishing instruments

Variety of instruments, are available in the market are commonly used for finishing and polishing procedures such as, abrasive systems include aluminum oxide, carbide compounds, diamond abrasives, silicon dioxide, zirconium oxide and zirconium silicate and polishing devices such as coated abrasive discs and stripes, aluminum oxide or diamond pastes, stones, soft or hard rubber cups or points, and wheels or brushes impregnated with abrasives (Kumari et al., 2019). All these instruments and systems available as one-, two-, three- and four-step finishing and polishing system. The effectiveness of the polishing system depends on the hardness of the cutting particles and materials, and the production of smooth surface depends on the ability to cut the filler particles and organic matrix of the resin composites (Barcellos & Borges., 2013).

According to the number of clinical steps; single-step and multi-step. A single-step technique uses diamond materials that only required one step of polishing such as fine diamond bur , whereas a multi-step technique uses materials (usually aluminum oxide) discs that steadily decrease in abrasiveness from the most abrasive to the smoothest (Itanto et al., 2017).

To achieve highly polished resin composite restorations, a series of abrasive disks, ranging from coarse to finer grits, should be used in multiple steps (Sang et al., 2021). However, recently when compared multisteps technique to one steps technique resulted that the finishing and polishing procedures can be completed using a single instrument, and it appears to be as effective as multistep systems for polishing dental composites, even after a pre-polishing process (Sang et al., 2021). Therefore, One-step polishing systems were preferred to clinicians because they enable them to achieve a smooth surface on the composite restoration in fewer steps (Bashetty & Joshi., 2010).

Bashtty et al., in 2010 (Bashetty & Joshi., 2010). Concluded that for minifill-hybrid composites, the one-step polishing system POGO achieved better surface quality in terms of roughness than the multi-step system (super snap). It was comparable to super snap for packable composites (solitaire). When the POGO polishing instrument was used, minifill hybrid had a higher surface finish than solitaire. When the super snap method was used, there was no noticeable variation in surface roughness between the two components (Bashetty & Joshi., 2010).

Ugur Erdemir et al., in 2012 (Erdemir et al., 2012). Compared the one step polishing systems with multisteps systems regarding the surface roughness and microhardness of three nanocomposites (filtek supreme XT, ceram –X, and Grandio). They concluded that the smoothest and the lowest hardness surfaces were under matrix stripes (control) and that the one step polishing system POGO appears effective as multistep sof-lex systems (Erdemir et al., 2012).

The superior performance of POGO's may be attributed to the fine diamond powders used instead of aluminum oxide (sof-lex) and a cured urethane dimethacrylate resin delivery medium (Erdemir et al., 2012). Dimond is always harder than alumina; thus, it can result in deeper scratches on the surface of the composites, resulting in high roughness (Nair et al., 2016). In their research, Ergucu and Tukun discovered that the POGO produces an equally smooth surface for Grandio as those for Mylar (Erdemir et al., 2012).

In another study by, Nair et al., (Nair et al., 2016). In 2016 they examined nanofilled resin composite, and they found that using a multi-step F&P system was more successful and resulted in a smoother surface (Nair et al., 2016). This was achievable because a multi-step method employs many materials, ranging from the most abrasive to the smoothest, removing matrix and filler particles while still reducing surface roughness (Itanto et al., 2017). Watanabe etal., 2008 also concluded that a multi-step polishing technique would result in a smoother surface than a single-step diamond particle polishing technique (Watanabe et al., 2005).

Soflex Diamond (SD), a two-step polishing method, was launched a few years back (Sang et al., 2021). It has spirals of either aluminum oxide or diamond particles impregnated in thermoplastic elastomers, and tends to have a similar composition to the Enhance/Pogo system (Sang et al., 2021).

The final glossy surface achieved by polishing devices, according to Marigo et al., (Marigo et al., 2001). is determined by the shape of the instruments (cusp, discs, cons), the flexibility of the backing material in which the abrasive is located and the hardness of the particles (Sang et al., 2021).

Transparent matrices such as Mylar stripe are preferred to produce smooth surface finish with highest gloss, but it is difficult to achieve proper anatomical contour of the restoration with Mylar strip (Nair et al., 2016). In this circumstance, it has been found that the lowest surface roughness was found in the sample that in contact with matrix stripes, were lower than threshold mean roughness (Ra) value of 0.2 mm (Kumari et al., 2019).

2.9. Factor affecting the finishing and polishing procedures

The surface quality of these dental restorations is an important parameter influencing the clinical behavior. The clinician’s objective in esthetic restorations is to achieve the smoothest surface, which will minimize dental biofilm accumulation and stain retention and provide longevity (Neme et al., 2002). Several factor have an effect on finishing and polishing procedures of the resin composite:

1-The characteristics of the resin composite; such as particle size and filler content, have a significant impact on polishing processes and subsequent survivability (Senawongse & Pongprueksa., 2007). Therefore, the use of nanotechnology to improve resin composite surfaces has been one of the most significant advancements in recent years. Nanoparticle-based composites have improved filler technology, changed organic matrixes, and a higher degree of polymerization, all of which increase mechanical and physical characteristics (Yazici et al ., 2010). The resultant different in roughness in the finishing and polishing techniques may be ascribed to distinct patterns of particles size and their arrangement within the resin matrix (Jung et al ., 2002). Because the resin matrix and the filler particles have different hardness and so do not abrade to the same degree (Nagem-Filho et al., 2003). On account of this, it is likely that microfilled, hybrid and packable composite resin do not achieve a comparable surface smoothness even when submitted to the same procedural finishing and polishing techniques (Barbosa et al., 2005).

2-The finishing and polishing(F&P) protocol was always a significant and stronger factor than the type of material (Lassila et al., 2020). The polishing efficacy of F/P materials is related to the hardness of the embedded abrasive particles, the flexibility of the backing material itself, and the shape of the instrument used (Lassila et al., 2020). Marigo et al., 2001 reported that the final glossy surface obtained by polishing depends on the flexibility of the backing material in which the abrasive is embedded, the hardness of the particles, and the instruments and their geometry (cusp, discs, and cones) (Marigo et al., 2001). For a resin composite restorative material finishing system to be effective, the abrasive particles must be relatively harder than the filler materials (Fruits et al., 1996).

3. **Additional factors** can affect the finishing and polishing results, including the amount of pressure utilized while polishing, the orientation of the abrading surface and the amount of time spent both with each abrading surface and abrasive material should be considered for evaluating the clinical efficiency among the polishing systems available today (Yadav et al., 2016).

A) finishing and polishing motion: finishing and polishing procedures require a sequential use of instrumentation in order to achieve a highly smooth surface, where the different hardness and degree of the contents of the composite material can affects the outcome (Eden et al., 2012). A planar motion was used for all specimens, as a previous study demonstrated that this motion produced significantly lower mean surface roughness values (Watts et al., 2003). Regarding the use of finishing bur and it is relationship with surface roughness and microleakage; literature reported that it is mostly necessary to use diamond or carbide burs to contour anatomically structured and concave surfaces (Ozgunaltay et al., 2003). Brackett et al., 1997 reported that the use of carbide burs for finishing procedures caused a higher degree of leakage than other methods tested. However, the results of the study revealed that diamond finishing bur was showing similar microleakage with Mylar strip (Brackett et al., 1997). Technique of the finishing and polishing there was significant difference between the nanohybrid composite resin surface roughness. This might be due to the difference in the techniques used in each study (Khorgami et al., 2017). Fruits et al., 1996 showed that a one-way motion produced a lower roughness level than other motions (Fruits et al., 1996). Moreover, researchers Reported that specimens polished with planar motion (sof-lex disks) gave lower surface roughness values than the specimens polished with rotary motion (shofu) in microhybrid and nanofilled composites (Kumari et al., 2019).

B) The pressure applied during finishing and polishing: according to auother, pressure would gather more on the irregular filler and increase the chance of the filler detaching from the resin surface (Patel et al., 2016). When the larger filler detached from the matrix, it would create a large hole on the surface and increase surface roughness. Another polissible explanation for higher surface roughness is that the nanomer and nanocluster would detch first along with softer matrix during polishing. This would increase surface roughness (Patel et al., 2016).

C) Immediate and delay finishing and polishing. The F&P time can be performed immediately after light cured resin composite material has been polymerized or 5 minutes after the initial hardening of self-cured material (Kumar et al., 2016). Finishing and polishing procedures should be performed immediately as much as possible after curing (Kaminedi et al., 2014). This assertion is based on the fact that hygroscopic expansion improves marginal adaptation by filling the gap left by polymerization shrinkage and finishing/polishing procedures. As a result, most dentists tend to complete the finishing and polishing process directly after the resin restoration has been light-cured, as this is more acceptable and cost-effective to the patients (Kaminedi et al., 2014).

It has been reported that delay F&P of polyacid modified composite resins resulted in smoother surface. They attributed this result to the maturity of the restorative material at the time of F&P. Delay F&P increased the hardness of the tested materials (Manojlovic et al., 2016).

In clinical practice, it is essential to determine which finishing and polishing method and time provide the best outcomes for esthetic restorative materials (Madhyastha et al., 2017). The timing of finishing/polishing procedure might have an effect on the physical properties of the composite and might increase the risk of premature failures (Kaminedi et al., 2014). However, in restorative process, the efficiency of finishing/polishing techniques on restorative surfaces is a critical concern. Since finishing and polishing procedures are typically performed directly after polymerization, this prematurity may make the restorative material more vulnerable to heat generation effects. Delayed finishing/polishing can make the restorative material more resistant to heat generation's negative effects (Da Silva et al., 2010).

Several scholars have proposed that delaying polishing by 24 hours would result in improved marginal sealing (Venturi et al., 2006). Therefore, several authors suggested delaying polishing because immediate polishing will cause plastic deformation of resin that is 75% cured after 10 minutes. Because of the possibility of fracturing of the unsupported enamel covering the marginal gap, any finishing procedures should be postponed until after hygroscopic expansion has occurred (Lia Mondelli et al., 2016).

Auother concluded that advantages of delayed finishing over immediate finishing depended on the material and tooth structure (Kaminedi et al., 2014).

However, in another study they found that delay finishing and polishing resulted in a rougher surface on both forms of composite restorations than immediate polishing and finishing. This may be due to the pressure generated by the delayed polishing. These findings support the findings of Yazici et al., (Yazici et al., 2010) but contradict Yap et al.,(Yap et al., 1998) who found that delaying the finishing and polishing of polyacid-modified resins resulted in a cleaner surface. This finding was attributed by the authors to the resin's maturity at the time of finishing and polishing (Kaminedi et al., 2014).

The residual roughness of esthetic materials after finishing and polishing with various techniques can be due to distinct patterns of particle size and their structure within the resin matrix. Cutting particles must be harder than filling particles for a finishing device to be effective; otherwise, the abrasive medium would just abrade the softer matrix. Surface roughness can increase as a result of this. As a result, the effectiveness of finishing and polishing procedures on the surface of restorative materials could be more important (Rai & Gupta, 2013). As the particle size in the microhybrid is bigger, resulting in a rough surface due to the plucking out of filler particles after the resin matrix has worn out during polishing (Da Costa et al., 2007).

Delaying finishing and polishing, on the other hand, provides a surface that is similar to or even harder than that obtained with immediate finishing and polishing, according to another analysis (Chinelatti et al., 2006).

Several researchers have proposed that delaying these finishing and polishing procedures by 24 hours would result in improved marginal sealing (Venturi et al., 2006). Moreover, based on the result of another study, when compared immediate and delayed finishing and polishing. The results of surface roughness of the materials in (24h) showed that least roughness values when compared to delayed (1week) (Madhyastha et al., 2017).

Yazicia et al., In 2010 evaluated the effect of the delay finishing and polishing on the surface roughness, hardness and gloss of four different resin composite restorative materials flowable resin composites (Tetric flow), hybrid resin composite(venus), a nanohybrid resin composite(Grandio), and polyacid modified resin composite (Dyract

Extra) Ten specimens from each restorative material were finished and polished immediately after the polymerization; the other 10 were finished and polished 24 hours later. The resin 10 specimen served as control. Finishing was done with 30 µm diamond finishing burs then polishing was done by Sof-Lex aluminum oxide discs (Medium to super-fine) were used for polishing all materials. The authors concluded that smoothest surfaces were obtained under Mylar strip (control) with lowest hardness. There was no significant difference in surface roughness values of immediate and delayed finished/polished. However, the delay polishing resulted in higher gloss and lower roughness than immediate polishing. Except in flowable composite the immediate polishing gives better result than delayed polishing (Yazici et al., 2010).

Madhyastha and collages., 2015 compared the effect of finishing and polishing systems and the finishing and polishing time on surface roughness and hardness of silorane based (FiltekP90) and methacrylate based (Z100) restorative materials. Finishing and polishing system were: A - Diamond burs with soflex discs; B - Diamond burs with Astropol polishing brush; C – Tungsten Carbide burs with soflex discs; D - Tungsten Carbide burs with Astropol polishing brush. Forty specimens of each restorative material were made using Brass molds (10 mm diameter x 2 mm thickness). To compared the effect of time period, specimens were finished and polished immediately and another delayed by a week. They concluded that delayed finishing/ polishing of materials was better than immediate polishing for both tested materials. Among all the polishing system Diamond bur- Astropol and Astrobursh combinations give better results for silorane based composites (Filtek P90). Whereas Tungsten carbide bur - Soflex disc used showed good surface finish in methacrylate based composites (Z100) (Madhyastha et al., 2015).

Madhyastha et al., in 2017 evaluated the effect of immediate polishing, after 24h and after 1 week, on the surface roughness of silorane-based microhybrid composite (filtek P90), methacrylate based hybrid composite(Z100), resin modified glass ionomer GIC and compomer. Using four systems (diamond bur + soflex discs; diamond bur + Astropol polishing brush; tungsten carbide bur + soflex discs; tungsten carbide bur + Astropol polishing brush). Surface roughness was measured using surface profilometers. The authors concluded that the immediate polishing was better than delayed polishing. Among the materials, microhybrid composite (Filtek P90) had the least Ra values representing the smoothest surface between all materials Comparison of polishing. Polishing system used diamond bur–Astropol and Astrobursh showed good surface finish (Madhyastha et al., 2017).

In recent study by Kaminedi et al., In 2014 authors evaluated the effect of finishing time and polishing time on surface roughness and microhardness of microhybrid composite and nanohybrid resin composites. The specimens were divided into 5groups according to the time of finishing and polishing (Immediate, after 15 min, after24 h and dry). Finished Composite under the Mylar strip without finishing and polishing was taken as the control group. Surface roughness was measured with scanning electronic microscope (SEM) and microhardness was determined using Vickers Microhardness test. Finishing was completed with 30 µm diamond finishing burs. Medium to super-fine aluminum oxide disks (sof-lex 3M ESPE, USA) were used for polishing. Authors found that: smooth surface with low hardness was obtained for the group using Mylar strip without finishing and polishing. The highest roughness was recorded for delayed finishing and polishing for both composites. Immediate finishing and polishing increased the surface hardness more than that in the Mylar stripes in both types of composites. According to the authors, dry finishing reduced the hardness significantly for microhybrid composite, but resulted in the highest surface hardness for nanofilled composite. Assumption authors added that: Immediate finishing and polishing under coolant resulted in the best surface smoothness and hardness values in microhybrid composite; but, immediate dry finishing and polishing provided the best smoothness and hardness values in nanohybrid composite. i.e., immediate or delayed finishing, and polishing under dry or wet conditions affecting the physical properties of the resins (Kaminedi et al., 2014).

D) Effect of wet and dry finishing and polishing: The surface strength of the nano-composite resin material increased significantly in the dry finishing process, while the hardness of the surfaces of hybrid composite material increased insignificantly. This finding was anticipated due to the heat-induced maturation of the resin matrix in the absence of a cooling system. however, this unregulated heat will result in numerous cracks and unnecessary roughness of the resin restoration's surface (Morgan., 2004).

On the other hand, the heat that generate from dry finishing and polishing, will influences the interaction between the tooth and the adhesive bond, as well as the bond between the particles and the matrix. To minimize the negative effects of dry finishing and polishing, it is advised to polish the resin under water coolant; thus, polishing dry or with coolant changes the physical properties of the composite (Lopes et al., 2002).

Surface roughness of the composite may increase during dry finishing and polishing because abrasive particles separated from the polishing tool may become embedded in the composite surface. Furthermore, a concentration of separated particles on the polishing tool's surface might reduce its efficacy in smoothing the surfaces (Dodge et al, 1991).

Nasoohi and coworker investigated the influence of dry and wet finishing and polishing on surface roughness and hardness of four microhybrid and nanohybrid composites. Their results revealed that finishing and polishing composite samples without the use of a water coolant enhanced the surface roughness and hardness of the samples (Nasoohi et al., 2017). The explanation was that Grandio nanohybrid composite comprises 1µ glass particles that stick out from the surface and enhance surface roughness. Therefore, it had the maximum surface roughness following both wet and dry finishing and polishing (Yazici et al., 2010). Jung et al., tested a number of nanohybrid resin composites resins and discovered that only the Grandio composite had a rougher surface than the hybrid composites (Jung et al., 2007).

Since the resin composite is a poor conductor of heat, the heat produced by the polishing procedures is trapped in the outer layer of the material. Raises the temperature above the glass transition temperature, hardening the surface and improving mechanical restoration properties including microhardness and abrasion resistance (Davidson et al., 1981).

2.10. Surface roughness:

The surface roughness is an important property to evaluate the surface integrity of the restorations determining the polishing ability and wear rate of these materials (Tanoue et al., 2000). The roughness of the surface has a significant relationship with gloss of resin composites (Lassila et al., 2020). Gloss is a visual quality that results from the geometrical distribution of light reflected by a surface. A smooth surface with minimal restoration roughness is associated with a high surface gloss (Heintze et al., 2006). Resin composite with a high gloss surface offers a restoration with a natural, esthetic appearance (Lassila et al., 2020).

A rough surface negatively impacts on the restoration's aesthetics which makes them susceptible to exterior staining and also diminish the amount of gloss, reducing the ability to reflect light. This is turn affects the perceived color of the composite resin and loss in aesthetics occurs due to staining (Furuse et al., 2008).

For resin composites, initial surface microhardness increases as surface roughness decreases (Hyun et al., 2015). Furthermore, rough surfaces are unattractive and cause discoloration of the restoration, plaque accumulation, secondary caries development, and gingival irritation (Kumari et al., 2019). In vivo investigations of effect of surface roughness (Ra) on bacterial plaque retention have revealed that an average roughness greater than 0.2 μm is related with a significant increase in bacterial retention (Martin&Spiller., 2012). Additionally, a rough surface can cause patient discomfort due to the sensitivity of the patient's tongue to a perceived roughness and 0.3μm is thought to be the threshold at which patients will detect a difference (Jones et al., 2004).

There are many variables that can influence the surface roughness of a dental material, such as the type of material, polishing system, force and timing of polishing, and polishing in wet or dry conditions (Wheeler et al 2020). Therefore, the roughness of the composite restorative materials is generally related to the composition of the materials as well as the finishing and polishing procedures (Jung et al., 2007). It was also reported that the different shapes and sizes of composite fillers, even in the same resin composite type, affected the surface morphology of resin composites subjected to finishing procedures (Jung et al., 2007). For this reason, comparing the numerical data of various research can be difficult because of numerous factors that can influence the outcomes (Wheeler et al., 2020).

In vitro research cannot reproduce the dynamic oral environment and therefore there are other factors that can influence the amount of the immediate surface roughness of a finished restoration, namely the type of composite and polishing system, the force applied and the amount of time spent in polishing (Wheeler et al., 2020). Several intrinsic and extrinsic factors influence the surface roughness of resin composites: Type of material, type of filler, shape, size, and distribution of filler particles, degree of polymerization, resin matrix composition, and filler/matrix bond strength are all intrinsic aspects (Marghalani, 2010). The flexibility of the polishing tool, the hardness of the abrasive particles, the geometrical form of the polishing tool, and the technique of application are all extrinsic factors in the finishing and polishing process (Hyun et al., 2015).

Color stability seems to depend more upon the finishing/polishing procedure than the material chemistry, while for surface roughness outcomes, both the finishing/polishing system and material chemistry showed strong effect (Wheeler et al., 2020). There is a significant correlation between surface roughness and color stability, where higher surface roughness values correspond to greater color differences. A finishing and polishing protocol with carefully planned steps, taking the necessary time, will improve the surface properties of the resin composite, leading to durable outcomes (Wheeler et al., 2020).

Methods of measuring surface roughness:

1-Mechanical profilometers with limited two-dimensional information are routinely employed to quantify surface roughness in vitro experiments (Da Costa et al., 2007). The surface of a specimen is scanned to obtain a two- or three-dimensional profile in profilometry, which can be done with either a contact or non-contact measuring equipment. The surface is scanned with a stylus with a diamond or steel tip in contact profilometry. A probe of laser light is used in non-contact profilometry (white or blue light). Depending on the sensor, the vertical range for white-light non-contact profilometry ranges from 300 m to 10 mm. This allows good flexibility when it comes to evaluating deep erosion pits and even curved natural surfaces. Flattened specimens, on the other hand, are necessary for optimal sensitivity and precision. Before utilizing polished specimens in experiments, it is routine practice to examine their flatness. The major disadvantage of a mechanical profilometer is that the stylus can't detect imperfections smaller than its own diameter. To quantify surface roughness, a 3-D laser surface profilometer was utilized since it allows for non-contact, rapid, quantitative surface measurements with no sample deterioration. In addition, the 3-D laser profilometer uses a light beam that sweeps across the sample surface, allowing for more precise angstrom level variation detection (Joniot., 2000).

2-SEM (Scanning Electron Microscopy) is a type of microscopy that SEM (LEO 1455 VP, Germany) was employed at 500 and 1000 magnifications to examine the surface qualitatively. The Zachrisson and Arthun (Z&A) index was used to assign a score to each tooth (Zachrisson & Arthun ., 1979):

__ Score 1: regular surface (minor scratches and some intact composite).

— Score 2: acceptable surface (many deep scratches, no intact composite).

—Score 3: defective surface (many large, deep scratches, no intact composite).

— Score 4: unacceptable surface (large, deep scratches and deeply marked surface)

3- Atomic force microscope is another way for determining mean surface roughness was to use tapping mode atomic force microscopy to create three-dimensional (3D) AFM pictures at 10 m ×10 m planes, 512× 512 resolutions, and a scan rate of 1.97 Hz in tapping mode (Karatas et al., 2020).

2.11. Microhardness:

Microhardness, flexural strength, flexural modulus, and fracture toughness are physical properties of restorative materials that impact the quality and longevity of restorations (Shannon et al., 1993).

Hardness is defined as a quantitative measure of resistance to deformation, and is calculated as the maximum applied load divided by the projected contact area (Ehrmann et al., 2019). Hardness is the material resistance against local plastic deformation. Therefore, hardness is affected by stress field around the indented material which has influence on the plastic deformation at this region (Obrien., 2008). Moreover, Hardness of resins composite is another essential feature connected to the degree of polymerization of the material, which influences composite wear resistance as well as wear of opposing teeth or restorations (Anusavice et al., 2012).

Surface hardness is a crucial mechanical property that predicts wear resistance and its severity able to abrade or be abraded by competing dental forces materials or structures (William., 2005). Therefore, changes in hardness may indicate the condition of a material's setting reaction, as well as the existence of an ongoing reaction or the restorative material's maturity (Venturi et al., 2006).

There are several factors that can influences surface hardness; the type and form of filler particles, their composition and distribution, the proportion of filler particles, and the type of resin all influence composite (Marghalani., 2010). The hardness of the resin composite is directly affected by the hardness of the filler particles (Tchorz et al., 2011).

Microhardness is measured with two different tests, the Vickers or Knoop tests, which differ by the shape of their indenters. A square base pyramid is used for the Vickers test, and a diamond base for the Knoop test. Vickers hardness is based on the ratio between the applied load and the true area of contact, whereas the Knoop hardness considers the projected area. Therefore, for optimal accuracy, the Vickers test was commonly used chosen (Ehrmann et al., 2019).

Hardness improved in all resin types during immediate finishing and polishing. In nanofilled composites, the decrease in strength due to delayed finishing was not important, but it was significant in microhybrid composites. The discrepancy between the two resins may be due to the matrix and filler components of the resin. These findings are consistent with those of (Cenci et al., 2008). They contributed the lack of surface properties after polymerization using a delayed polishing technique to the decline in hardness (Cenci et al., 2008).

The loss of hardness or discoloration of the surface is caused by insufficient polymerization on the outer surfaces. To create a more wear-resistant, harder, and color-stabilized restoration, the outermost composite should be removed using finishing and polishing processes (Park et al., 2004). As this layer is high in resin matrix (oxygen inhibition layer), less abrasion resistant, and can include bubbles (Bijelic-Donova et al., 2015).

Methods of measuring microhardness:

Hardness measurement is a product of a specific measuring process, not an inherent quality of the material. Essentially, an indenter of a given form is pressed into the surface of the material to be tested under a specific load for a predetermined time period, and the size or depth of the indentation is measured once the force is released. For more than a century, indentation or scratch tests have been performed to measure the hardness of materials (Tabor., 1970).

The hardness test has become one of the most used methods of characterization for resin composites due to its simplicity of use. There was standard way of determining the hardness of a material - Brinell, Knoop, Rockwell, or Vickers (ISO2039.1., 2010; ISO4545-1, 2005; ISO6506.1., 2014; ISO/CD6507-1, 2006)

1- The Vickers hardness test involves indenting the test material with a diamond indenter in the shape of a pyramid with a square base a test force ranging from 1 gf to 100 kgf. Normally, the whole load is applied for 10–15 seconds. A microscope is used to measure the two diagonals of the indentation left in the material's surface when the load is removed, and the average is determined. The Vickers hardness is calculated by dividing the load by the indentation's square area. The Vickers hardness number, as well as the test force and dwell duration, should be recorded (ISO/CD6507-1, 2006).
2- A Knoop hardness test a predetermined test force is applied for a specific dwell duration using a pyramid-shaped diamond indenter (ISO4545-1, 2005; Poskus et al., 2004). The initial application of the force should not take more than 10 seconds, and the test force should be sustained for 10–15 seconds. The test force divided by the projected area of the indentation gives the Knoop hardness value. The indenter used in a Knoop test is more elongated in form than a Vickers indenter. While the indentation length on the vertical and horizontal axes is measured and averaged in the Vickers hardness test, the Knoop technique only employs the long axis (Poskus et al., 2004).
3- Rockwell hardness test (ISO2039-2) the Rockwell technique is used to determine the permanent depth of indentation caused by a force or load applied to an indenter. the difference in indentation depth between the preload and primary load values This distance is turned to a number of hardness (ISO2039.1., 2010).
4- The Brinell test this technique involves applying a specific test load on a carbide ball of fixed diameter, holding it for a predetermined amount of time, and then removing it. The indentation's permanent width is then measured over at least two diameters—usually at right angles to each other—and the findings are averaged. Brinell hardness is calculated by dividing the test force by the indentation's surface area. Brinell testing, like other indentation procedures, has the biggest source of error in the measurement of the indentation; as a result,

the approach is rather subjective and operator dependent. Brinell hardness tests are less commonly used to test resin composites (ISO6506.1., 2014).

2.12. Studies investigated the effect of finishing and polishing protocol on the surface roughness and microhardness of dental resin composite.

Bashetty et al., (2010) evaluated the effect of two finishing and polishing procedure on the surface roughness of minifill- hybrid composites Esthet-X and packable composite Solitaire. A total of forty-two discs (10 × 2 mm), 21 specimens of each restorative material were prepared. After being ground wet with 1200 grit silicon carbide paper. Each composite group was divided into three subgroups according to polishing method 1). Control group no finishing and polishing, 2) One-step PoGo (Dentsply/Caulk, Milford, DE, USA), 3). Multi-step Super Snap (Shofu, Inc. Kyoto, Japan). The surface roughness was measured using a profilometer. The result of their study indicate that the Mylar stripes produced the smoothest surface in all materials and among the finishing and polishing methods. The one-step polishing system (PoGo) produced smoother surface than the multi-step system (Super Snap). The minifill hybrid composite was better surface than packable composite. The authors concluded that the effectiveness of one step polishing system emerge to be as effective as multistep systems as well as fewer clinical step which is more desirable to the clinician in daily practice (Bashetty et al., 2010).

Eden et al., (2012) compared the effect of four different finishing and polishing procedures on surface roughness, microhardness and microleakage of nanohybrid composite (Ceram X mono, Dentsply, Detrey, Konstanz, Germany). The sixty specimens were divided into four subgroups (n=15). Group 1: Mylar strip: no procedure after curing. Group 2: Diamond finishing bur (the cured surface of the specimens with the Mylar strip were finished using 10 strokes diamond bur #4219FF - KG Sorensen, Barueri, SP, Brazil). Group 3: Procedures in Group 2 followed by medium, fine and super-fine aluminum oxide-impregnated discs (Sof-lex, 3M ESPE Dental Products, St. Paul, MN, USA) under dry conditions with light hand pressure for 30 seconds without water cooling. Group 4: Procedures in Group 2 followed by diamond impregnated cured urethane dimethacrylate resin polishing devices (Pogo, Dentsply DeTrey, Konstanz, Germany). A profilometer was used for assessing surface roughness (Ra). Microhardness measurements on cured surfaces of the specimens were measured by Vicker's hardness Test. The smoothest surface was observed in PoGo group with the highest microhardness. There was no significant difference in R value between Mylar strips and PoGo polishing system. About microhardness scores, there was no significant difference between Mylar strip=diamond finishing bur which resulted in the lowest hardness. The authors concluded that the reduced number of steps (one-step polishing system) appears to be more effective than multi-step system and may be preferable for polishing resin composite restorations (Eden et al., 2012).

In another study by Nasoohi et al., (2017) analyzed the effect of dry and wet finishing and polishing on surface roughness and microhardness of four resin composite (microhybrid and nanohybrid composites). Polofil supra, All-purpose Body were microhybrid, and Grandio and Aelite Aesthetic Enamel nanohybrid. A total of thirty sample were finished with different finishing and polishing Sof-lex Pop-on Discs and aluminum oxide discs. The subgroup exposes to dry finishing and polishing D, wet finishing and polishing W and group C not exposed to finishing and polishing under Mylar strip served as control group. The results of their study demonstrated that the surface polymerized against a Mylar strip was the smoothest surface with lowest microhardness. So this assessed the fact that the finishing and polishing without water coolant increased the surface roughness and microhardness. In all composite samples, Graindio samples nanohybrid composite showed higher roughness and the highest hardness value compared to other composite resins because this composite has 87wt % filler content which is higher than other composite. Moreover, it has been reported that the flexible aluminum oxide discs are perfect for gaining a smooth composite surface (Nasoohi et al., 2017).

Kumari et al., (2019) compared the effect of different polishing system on the surface roughness and microhardness of a Nano filled and Universal submicron hybrid composite. One hundred twenty specimens of composite resin the specimens were divided into two group according to type of composite; Group 1-Universal submicron hybrid composite group 2- Nanofill composite resin. Each group was then divided into subgroups according to type of finishing and polishing procedures n= 15 in each subgroup A control group: no finishing and polishing, B: Politip, C: Soflex diamond polishing system and D-Optidisc4200.The surface roughness was measured by profilometer with evaluation of surface topography. Microhardness was done by atomic force microscope and microhardness tester. The smoother surface was observed in soflex diamond group compared to the sample in politip and optidisc. The roughness value for soflex was0.1135mm. Also the microhybrid composite resins demonstrated substantially higher smoothness (0.0141mm) than Nanofill composite resin (0.0905mm) under matrix strips. In contrast, the surface hardness of two type of composites the Nanofill composite (filtek Z350) showed higher surface hardness than universal submicron hybrid composites. In conclusion, the Nano filled composite showed more resistance to fracture so can be used more in area exposed to masticatory force and the submicron hybrid composite can be used in esthetic area (Kumari et al., 2019).

Ehrmann et al., (2019) measured the surface roughness and microhardness of five nanocomposite polished with two different fluted finishing bur and evaluated the effectiveness of these finishing on the surface roughness by optical profilometer and scanning electron microscopy. Microhardness was tested with a Vickers indenter. The resin composites evaluated were (Filtek Z500, Ceram X Mono, Ceram X Duo, Tetric Evoceram, and Tetric Evoceram Bulk Fill). A total of 60 specimens were fabricated. Two specimens of each type of resin composite cured under Mylar strips served as control group 12 specimens of each type of composite were subgrouped into1). MS two specimen no finishing and polishing 2). QB system (Five specimens) Q crosscut 12/15-fluted finishing bur, then an EVO-Light polisher. These 5 specimens were polished using this finishing–polishing sequence system under water spray cooling. 3) QWB system (5 specimens): a blue-and-yellow-ring Q crosscut 12/15-fluted finishing bur, then a white-ring crosscut 30-fluted polishing bur. then an EVO-Light polisher on a blue-ring contra-angle. the smoothest surface with lowest hardness was obtained under Mylar stripes and the QWB system produce the lowest roughness highest hardness values for all type of composites Thus, there was no significant difference between the QWB system and Mylar stripes which the QWB produced the best surface finish for all the nanocomposites, According to SEM the QWB finishing and polishing sequence was significantly more effective than the QB sequence in terms of the final hardness and roughness of nanocomposite resins. Therefore, hardness and roughness for the 5 nanocomposites showed material dependency when using the QB and QWB finishing–polishing Filtek Z500, which includes the smallest filler particles, presented significantly the smoothest and harder surfaces in both finishing–polishing sequences.

Moreover, Ceram X Mono and Ceram X Duo are composed of large-diameter of glass filler. because of this the surfaces remained rougher even after high-quality finishing–polishing sequences (Ehrmann et al., 2019).

Babina et al., (2020) evaluated the effect of final surface treatment and dental composite type on the roughness of the composite surface, composite/enamel interface, and composite/cementum interface, as well as on the polishing time. Class V cavities prepared in extracted teeth (n = 126) were restored using one of the three nanohybrid composites with different filler sizes. The specimens were randomly assigned to three different finishing and polishing sequences. Finishing and polishing sequences used in their study were: AD—aluminum oxide abrasive discs; SP + IB—diamond-impregnated silicone polishers with aluminum oxide + brushes with fibers impregnated with silicon carbide abrasive particles; SP + PP—diamond-impregnated silicone polishers with aluminum oxide + polishing paste with aluminum oxide. The surfaces roughness was measured using the contact profilometer. They concluded that there was no significant influence of the composite type on the restoration surface roughness (p = 0.088), while the polishing method had a significant impact (p < 0.001). The Ra of the composites ranged between 0.08 µm and 0.29 µm, with the lowest values (0.09 µm ± 0.05 µm) found in the aluminum oxide disc group (p < 0.001). The interface roughness was significantly greater than that of the composite surface (p < 0.001), and depended on the composite type and polishing system employed (Babina et al., 2020).

In a very recent study by Freitas et al., (2020) authors evaluated the surface roughness and their color stability after immersion in a coffee solution. In addition, they also investigated the optimal finishing/polishing combination for reducing surface roughness and increasing stain resistance. Comparing them to traditional incremental-fill hybrid resin composite. Novel bulk-fill composites with variety of finishing/polishing procedures. Sixty discs were prepared from bulk-fill composites (Filtek™ Bulk Fill Posterior Restorative and Fill-Up™) and incremental-fill Filtek™ Z250. They were further divided according to different polishing procedures (n = 5): three multi-step polishing procedures or finishing with a bur (control). Surface roughness (Ra) was measured using an atomic force microscope. Resin composite type, polishing procedure, and their interaction had a statistically significant effect on surface roughness ($p < 0.001$) and color change ($p < 0.001$). FillUp™ exhibited the highest surface roughness. Filtek™ Bulk Fill registered the lowest surface roughness after the three-step polishing procedure. Higher surface roughness relates to greater color change. Where surface finishing was achieved by means of a diamond bur. Both parameters were significantly correlated and found to be material dependent and polishing-procedure dependent. Higher surface roughness relates to greater color changes (Freitas et al., 2020).

Sang et al., (2021) evaluated the effect of several finishing and polishing on the surface roughness (Ra) and gloss units (GU) of five dental composites. These materials included two microhybrid resin composites Filtek Z250 and Metafil CX, one nanofilled resin composite Filtek Z350XT, and two nanohybrid resin composites Ceram X one, and Venus Diamond. Polished with three systems (Sof-Lex XT, Enhance/Pogo, and Soflex Diamond) before/after simulated brushings and to determine the amount of time required to achieve maximum gloss. Ninety rectangular specimens (n=18 per composite) were prepared The Measurement of surface roughness and surface gloss at each polishing step, including baseline before polishing, the roughness value (Ra, µm) was measured with a profilometer. Six specimens of each composite were divided into one of the polishing systems. The Five polished specimens per composite were brushed with a toothbrush machine. The result of this study, the highest gloss and the smoothest surfaces were achieved after polishing and brushing abrasion procedures. Moreover, when using the Sof-Lex Diamond and Enhance/Pogo systems Filtek Z350XT exhibited the most stable and lowest Ra during the brushing cycles regardless of polishing system. And Z2 exhibited a lower Ra and lower GU values after the third brushing cycle compared to the other resin composite groups, polished with any F/P system showed rougher surfaces than before brushing, while the surface roughness of Z3 was less than or similar to that before brushing In the present study, CE exhibited higher Ra and lower GU than other resin composites after polishing, especially when using SX. In the present study, the resin composite surface using SD and EP systems had statistically lower Ra and higher GU compared to those with SX for all the resin composites after complete polishing procedures (Sang et al., 2021).

A recent study was conducted by Nithya et al., (2020) to evaluate the effect of three different polishing systems on the microhardness, surface roughness. The F&P was PoGo is a one-step polishing systems, Sof-Lex is a two-step polishing system, Sof-Lex

Pop-On is a three-step polishing system. The highest mean Ra value for all composite materials tested in their study was 0.82 μm which was produced by the Filtek Z-250 and one step F/P systems. Sof-Lex Spiral created significantly smoother surfaces than Sof-Lex Pop-On and PoGo F/P systems for all resin composites. Filtek Z-250 had significantly higher mean of microhardness Z-350 exhibited lower roughness and higher microhardness (Nithya et al., 2020).

Chapter 3

AIM OF THE STUDY

3.1 AIM OF THE STUDY

The aim of this in vitro study was to evaluate the: To evaluate the influence of three different finishing and polishing procedures on the surface roughness and microhardness of four composite resin restorative materials.

3.2 The objectives:

- To measure the surface roughness and microhardness of four types of resin composites using three different types of F&P systems.

-To evaluate and compare the three different finishing and polishing systems on the surface roughness of four resin composites.

-To evaluate and compare the three different finishing and polishing systems on the microhardness of four resin composites.

Chapter 4

MATERIALS & METHODS

MATERIALS AND METHODS

4.1. Materials:

Four different resin composite materials shade A2 were evaluated in this study namely:

- Microhybrid composite (Dynamic plus).
- Nano-hybrid composite (Nexcomp).
- Super-nano (ESTELITE Σ QUICK).
- Nanoceramic composite (ZENIT).

Three finishing and polishing systems were used in this study namely;

- Fine diamond finishing bur (DD3265) TOBOOM,
- Soflex discs (3M-ESPE, Dental Products, and St Paul, MN USA),
- Astropol® cups and discs (Ivoclar Vivadent, Amherst, NY, USA).

The detailed description and composition of the materials and finishing and polishing systems are listed in Tables; 4.1 and 4.2 according to manufacturers' data. Photographic image of the materials are illustrated in Figures; 4.1 and 4.2.

Table 4.1 Description of the resin composites used in the study

Materials name (manufacture)	Composition	Lot number	Expire date
I) Microhybrid; Dynamic Plus (President Dental) Germany	Resin matrix: Bis-GMA, UDMA, Bis-EMA Filler: zirconia/silica0.01–3.5 µm. 60vol%–84wt%	PD8N25A2	8-11-2021
II) Nano-hybrid; Nexcomp (META BIOMED, Korea)	Resin matrix: Bis-GMA, UDMA, Bis-EMA Filler: zirconia/silica 5－75 nm (filler), 0.6－1.4 µm (cluster) 59.5vol%–78.5wt%	NXC 1805281	24-6-2021
III) Super-Nano; ESTELITE Σ QUICK (Tokuyama Dental Corp.) Japan	Resin matrix: Bis-GMA, TEGDMA Filler: zirconia/silica, 0.1－0.3 µm 71vol%–82wt%	W973	06-2022
IV) Nano-Ceramic; ZENIT (President Dental) Germany	Resin matrix: UDMA, Bis-GMA, Bis-EMA Glass filler (medium grit size 0,7 microns) Pyrogenic silica (medium grit size 12 nm) Agglomerated nanoparticles (medium grit size 0,6 microns)	2019010265	04-2022

TEGDMA: Triethylene glycol dimethacrylate, UDMA: Urethane dimethacrylate, Bis-EMA: Bisphenol-A ethoxylated dimethacrylate, Bis-GMA: Bisphenol-A glycidyl dimethacrylate,

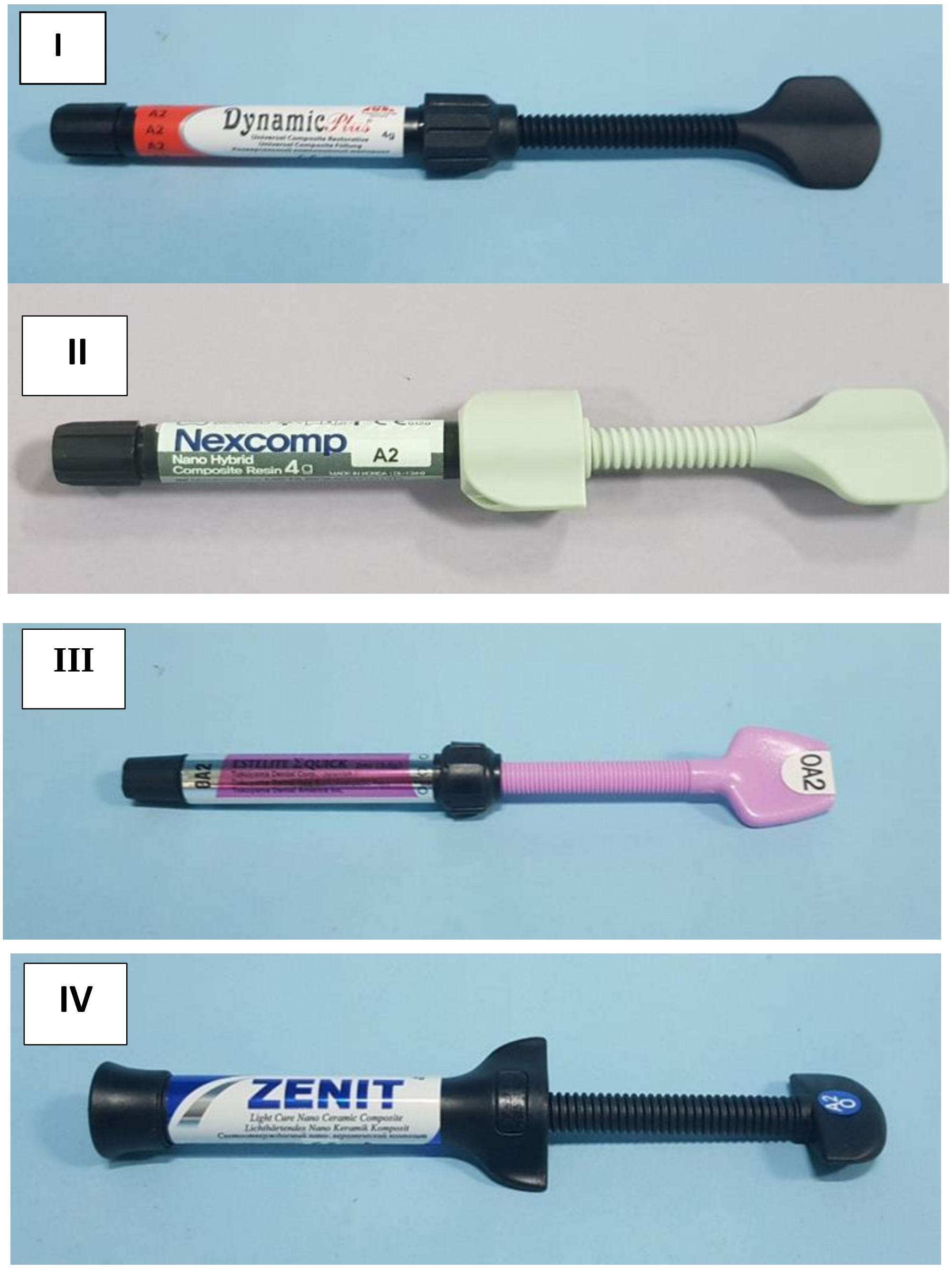

Figure 4.1: Photographic images of resin composites; I) Microhybrid composite (Dynamic plus) II) Nanohybrid composite (*Nexcomp)* III) Supernano composite (ESTELITE Σ QUICK) IV) Nanoceram composite (ZENIT)

Table 4.2 : Finishing and polishing systems used in this study

System	Composition	Application
Finishing bur (DD3265) TOBOOM Dental rotary instrument	Fine diamond finishing bur	Burs sequentially applied for 20 seconds each, using water – cooled hand piece, moved on single direction on the entire specimen surface followed by polishing paste. Each bur was used 3 times only
Four-step Sof-lex discs (3M-ESPE, Dental Products, St Paul, MN USA)	Coarse aluminum oxide disc (70-90µm), medium aluminum oxide disc (40µm), fine aluminum oxide disc (24µm), and super-fine aluminum oxide disc (8µm)	specimens were sequentially polished using intermittent light pressure for 20 s, rinsed, and dried with air syringe for 10 s.
Two-step Astropol® cups and discs (Ivoclar Vivadent, Amherst, NY, USA)	Two steps; F (grey; 45 µm) and P (green 1 µm): caoutchouc, aluminum oxide, silicon carbide, titanium oxide, iron oxide	repetitive strokes, 10 seconds per step of the system

Figure 4.2: Photographic image of **I**) Two steps finishing and polishing systems Astropol cups and discs. **II**) Four steps finishing and polishing systems Sof-lex discs.

4.2 Methods:

This study was conducted following veena kumara et al., (2019) and Ece Eden et al., (2012). This part explained how the experiment was performed in the following sections.

4.2.1 Specimen preparation and grouping.
4.2.2 Finishing and polishing procedures.
4.2.3 Measurement of surface roughness of resin composites
4.2.4 Measurement of microhardness of resin composites.
4.2.5 Statistical analysis.

4.2.1. Specimen preparation and grouping

A total of 160 disc-shaped specimens were prepared from four brands of composite resin materials of shade A2: Microhybrid composite (Dynamic plus), nano-hybrid composite (***Nexcomp***), super-nano (ESTELITE Σ QUICK) and nanoceramic composite (ZENIT) (Table 4.1). These 160 specimens were divided into four groups of 40 specimens in each group (n=40) depending on the composite material used **Group 1:** Microhybrid composite (Dynamic Plus), **Group2**: Nanohybrid (Nexcomp), **Group 3:** Supernano composite (ESTELITE Σ QUICK) and **Group 4**: Nanoceram composite (ZENIT). The detail distribution and description of the specimen number and testing groups were illustrated in figure 4.3. For each type of composite; the composite specimens were prepared by condensing the resin composite material into a metal mold of five circular holes (10 mm diameter and 2 mm thick) as shown in Figure 4.4. The mold was slightly over-filled with the resin composite material. A clear celluloid strip was placed below and over the mold, and then pressed between two glass slides to get homogenous specimens identical in size with flat surface. The glass slide was then removed and the specimens were light cured using a 1,000 mW/cm^2 strength LED (Light Emitting Diode-Elipar, 3M ESPE, Germany) light curing unit. The light output was checked using a radiometer. After the light curing procedure, the clear celluloid strips were removed, the cured specimens were finished with six strokes, in the same direction using 600 grit Buehler sandpaper (Lake Bluff, USA) to produce a standard rough surface. Specimens were water rinsed and stored in distilled water at 37˚C for 24h in an incubator prior to finishing and polishing procedures (3M, advanced tech, Cairo, Egy), Figure 4.5.

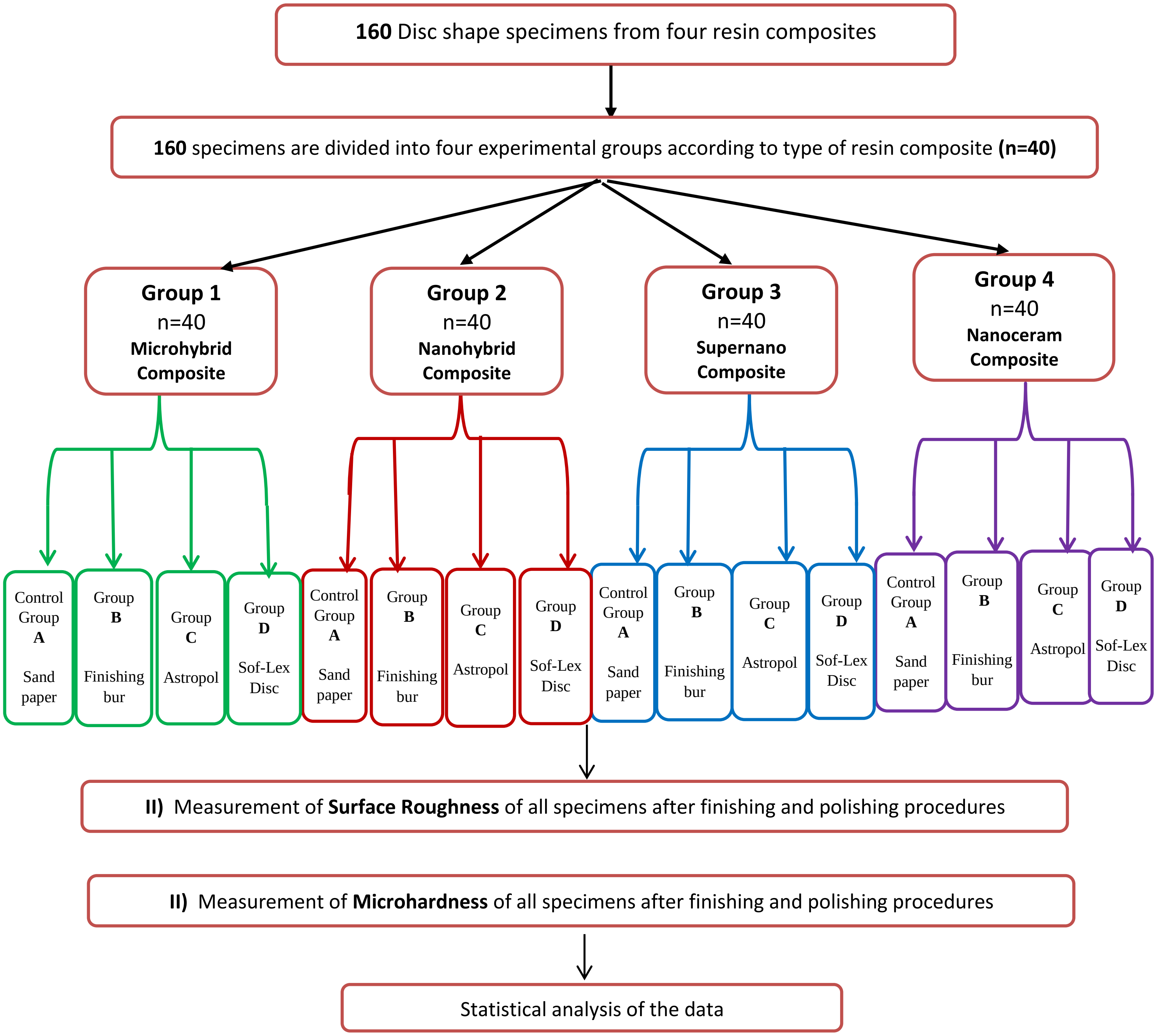

Figure 4.3: Flow chart shows of number of specimens'; distribution of testing groups and methodology steps

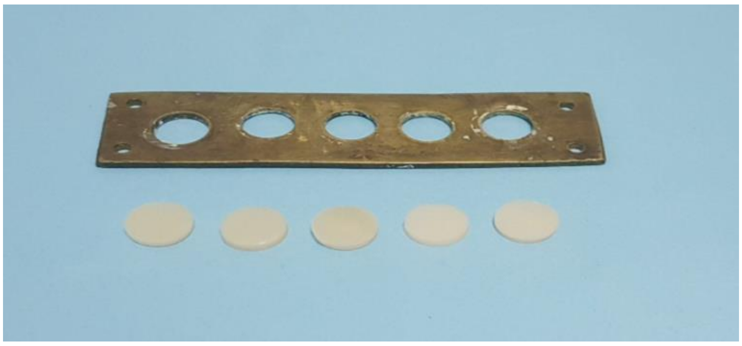

Figure 4.4: Photographic image of custom-made metal mold with the prepared disc shape composite resin specimens

Figure 4.5: Photographic image of the incubator

After 24 hours' water storage, for each type of composite, the group of 40 specimens was further divided into four sub-groups (A, B, C, D) based on the type of finishing and polishing procedure.

Group A-control group; the superficial layer of the cured specimens, which is the resin rich surface layer was removed with sand paper (Control group).

Group B- Procedure in group A followed by using the diamond finishing bur.

Group C- Procedure in group A followed by using the Two –step finishing and polishing system- Astropol® cups and discs (Ivoclar Vivadent, Amherst, NY, USA).

Group D- Procedure in group A followed by using the Four –step finishing and polishing –Soflex disc, aluminum oxide-impregnated discs. As shown in figure 4.3.

4.2.2. Finishing and polishing of composite specimens:

The finishing and polishing systems used were: **I)** Fine diamond finishing burs (DD3265) TOBOOM and polishing paste **II)** four steps Sof-lex discs (3M-ESPE, Dental Products, and St Paul, MN USA). **III)** Astropol® cups and discs (Ivoclar Vivadent, Amherst, NY, USA). The compositions, specifications and manufacturers for the polishing systems are listed in Table 4.2. Before the actual finishing and polishing procedures, a marking was made on the outer edge of each specimen to standardize the direction of rotating device application. The specimens were subjected to three different finishing and polishing systems. These systems and procedures were applied according to the manufactures instructions.

In Group A: (n=10) the superficial layer of the cured specimens which is resin rich surface layer was removed with sand paper (Control group).

In Group B: (n=10) Procedure in group A followed by using diamond finishing burs

In Group C:(n=10) Procedure in group A followed by using two-step finishing and polishing system Astropol® cups and discs (Ivoclar Vivadent, Amherst, NY, USA).

In Group D: (n=10) Procedure in group A followed by using four-step finishing and polishing system- Sof-lex discs, aluminum oxide-impregnated discs.

Specimens of each composite were randomly assigned according to the finishing and polishing systems, (n=10 for each experimental subgroup). Manufacturers‟ instructions were followed during the polishing procedures. Only one side of each specimen was polished, and marked with 1mm indentation for identification. The same low-speed hand piece W&H 758 Austern) at ≤ 25,000 rpm was used for all finishing and polishing systems. The finishing and polishing procedure used consisted of repetitive strokes, ten seconds per step of the system, to prevent heat build-up and formation of grooves. A conscious effort was made to standardize the strokes, downward force, and the number of strokes for each finishing and polishing procedure. Burs sequentially applied for 20 seconds each, using water –cooled low speed hand piece, moved on single direction on the entire specimen surface followed by polishing paste. Each bur was used 3 times only (Figure 4.6).

According to manufacturer’s instructions; the 4-steps Sof-Lex™ (3M-ESPE, Dental Products, St Paul, MN USA) discs were used dry coarse aluminum oxide disc (70-90µm), medium aluminum oxide disc (40µm), fine aluminum oxide disc (24µm), and super-fine aluminum oxide disc (8µm). Specimens were sequentially polished using intermittent light pressure for 20 s, rinsed, and dried with air syringe for 10 s (Figure 4.7).

The two steps Astropol® cups and discs finishing polishing system (Ivoclar Vivadent, Amherst, NY, USA) was used with water as follows; F (grey; 45 µm) and P (green 1µm): caoutchouc, aluminum oxide, silicon carbide, titanium oxide, iron oxide used with repetitive strokes, 10 seconds per step of the system as shown in figure 4.8

The other side did not receive any polishing treatment. After each finishing and polishing procedure, resin composite discs were washed to remove debris, then placed in individual vials containing 20 millilitres of distilled water and kept incubated at 37°C for 24 hours.

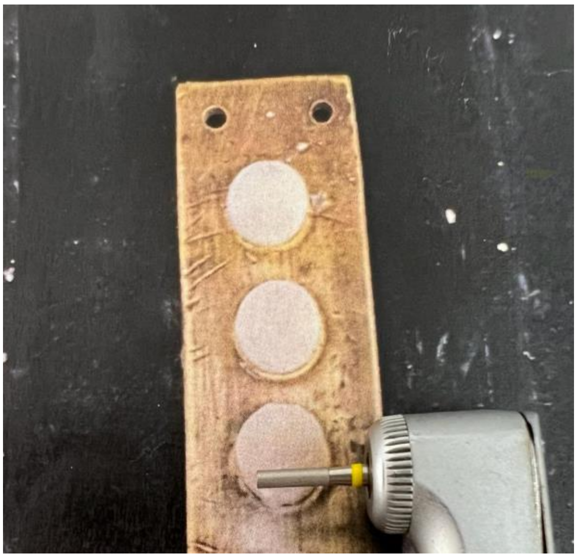

Figure 4.6: photographic image of finishing and polishing procedures by diamond bur

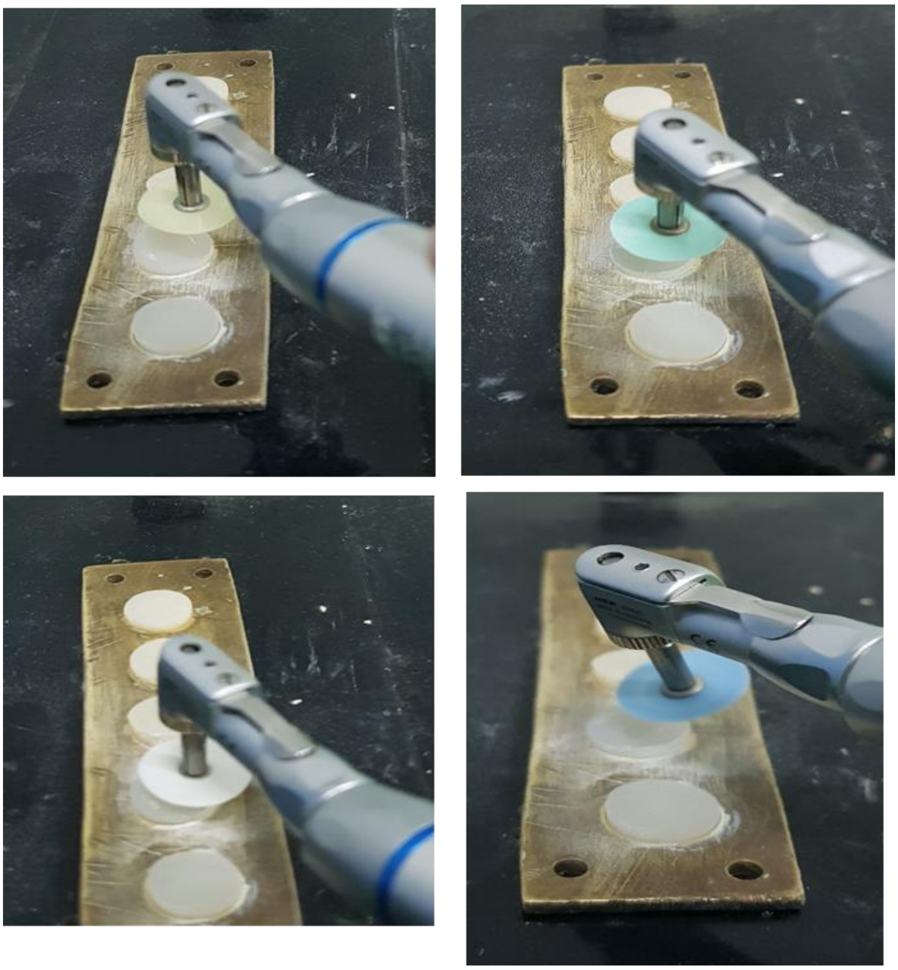

Figure 4.7: Photographic images of finishing and polishing procedures by Sof-lex discs, four-step system.

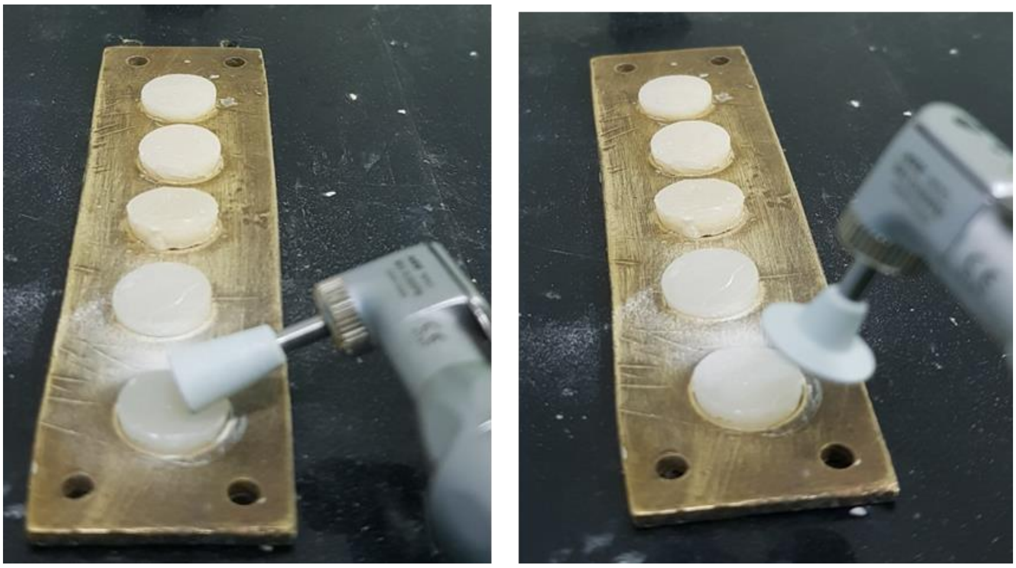

Figure 4.8: Photographic images of finishing and polishing procedures by Astropol cups and discs, two–step system.

4.2.3. Surface roughness measurement:

After 24 hours' water storage, all the specimens in all groups were subjected to surface roughness measurements after finishing and polishing procedures using USB digital surface profile gauge, (Elcometer 224/2, Elcometer Instruments, and Great Britain). The data were recorded using computer software (Elcomaster 2, Elcometer Instruments) (Figure 4.9). The mean roughness value was determined with an 8mm cut-off value for surface, and the traversing distance of the stylus was 5.0 mm. The radius of the tracing diamond tip was (2.5 µm), and the measuring force was 10 mN. The surface profile needle was positioned perpendicular over each test specimen performing three readings in different locations of the specimen surface. After the three readings, the mean surface roughness value was obtained. The roughness value (Ra) for each specimen was recorded as the average of these three readings. The machine was repeatedly calibrated after each five specimen's measurements to check the performance of the profilometer and to assure the reliable reading.

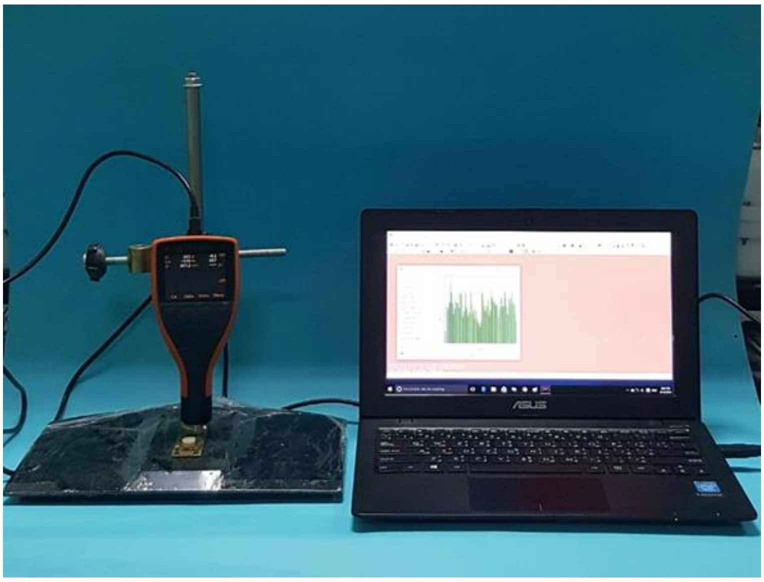

Figure 4.9: Photographic image of USB digital surface profile gauge used for roughness measurement.

4.2.4 Microhardness measurement

Microhardness measurements of the specimens were determined by Vickers surface microhardness device; Digital Display Vickers Micro-Hardness Tester (Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd. China) (Figure 4.10). Vickers hardness testing machine was used for specimen indentation with a Vickers diamond indenter and a 20X objective lens. Vickers microhardness reading were undertaken using a load of 100g applied to the surface of the specimens for 10 seconds. Three indentations were recorded from each specimen that were equally spaced over a circle not closer than 0.5 mm to the adjacent indentations (Figure 4.11). The indentations were made on the surface of each specimen, and the microhardness value (HV) was obtained as the average of these readings. The diagonals length of the indentations was measured by built in scaled microscope and Vickers values were converted into micro-hardness values.

Micro-hardness calculation: microhardness was obtained using the following equation:

$$\mathbf{HV=1.854\ P/d2}$$

Where, HV is Vickers hardness in Kgf/mm^2.

P is the load in Kgf.

d is the length of the diagonals in mm.

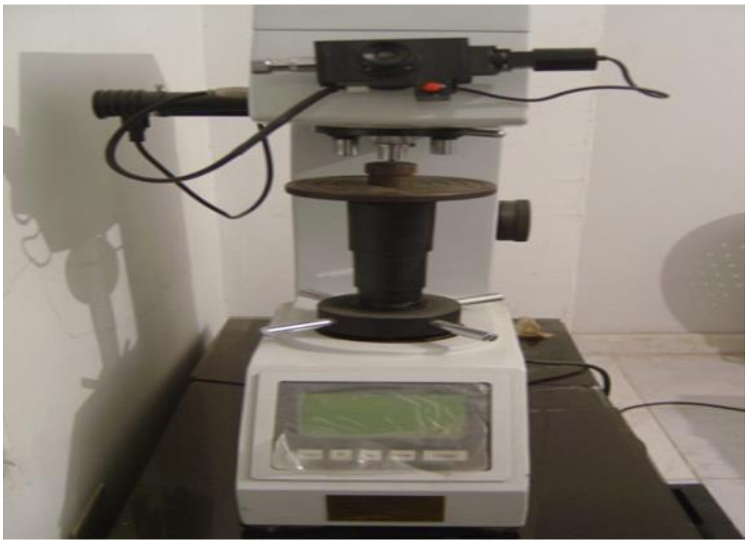

Figure 4.10: Photographic image of Digital Display Vickers Micro-Hardness Tester used for hardness measurement.

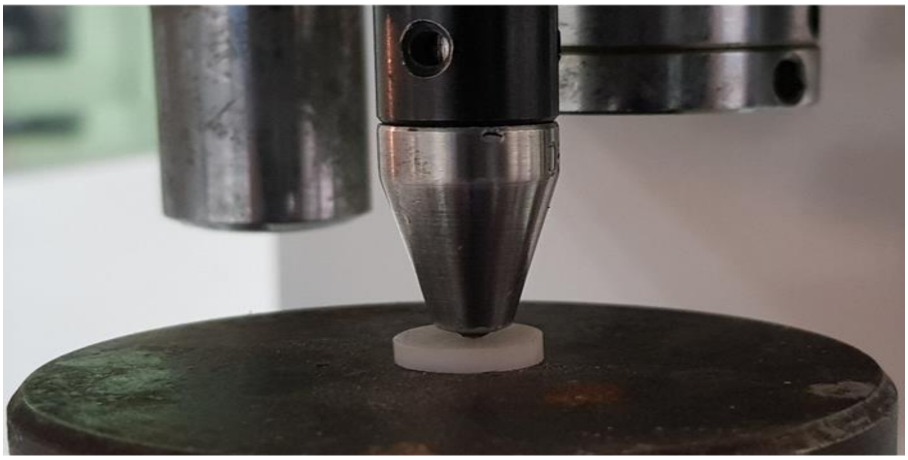

Figure 4.11: Photographic image of composite specimens mounted onto Vickers Micro-Hardness Tester during hardness measurement.

4.2.5 Statistical Analysis

The obtained values for the surface roughness (Ra) and microhardness (VHN) were statically analyzed using statistical package for social sciences (spss) for microhardness version 25 software. Means and standard deviations of surface roughness and microhardness were obtained for each tested group after finishing and polishing procedures.

Analysis of variance test (ANOVA) was used to evaluate the effect of finishing and polishing procedures on the surface roughness and microhardness of the tested resin composites.

To determine the significant differences, multiple comparison Tukey`s Post hoc test was performed. Statistical significance was set in advance at the 95% probability level (Probability value ≤ 0.05).

Chapter 5

RESULTS

Results

Statistical analysis

Kolmogorov-Smirnov and Shapiro-Wilks test results revealed that all variables followed a normal distribution. Therefore, to analyse the data, parametric methods were applied. Two-way ANOVA (general linear model) was used to compare mean values between groups and materials followed by Bonferroni post hoc tests for multiple pairwise comparisons. To analyze the data, the Statistical Package for Social Sciences (SPSS) software, version 25.0 (IBM SPSS Statistics for Windows, Armonk, NY) was used. Significance level was set at 5% ($\alpha = 0.05$).

5.1 Surface Roughness:

Table 5.1 shows the distribution of average roughness scores according to the type of composite and polishing techniques. It is clear that the control group using sand paper have higher roughness than other groups in all types of composites used (0.26). All differences between materials and polishing technique groups are statistically significant (P=0.000). However, the type of composite did not show significant effect on the polishing technique (P=0.365), Table 5.2 the average roughness in microhybrid and nanohybrid composite was homogenous and higher than the other types of composite but not statistically significant (P=0.124). There was no significant difference between polishing techniques but Astropol and soflex appeared homogenous and more comparable than other techniques, as can be seen in Table 5.3

Figure 5.1 shows the roughness produced by different polishing techniques when used with different types of composites. Except for nano-hybrid, Astropol showed higher roughness than other types of polish. Alternately, soflex demonstrated higher roughness with nanohybrid composite than other types of polish. Overall, Supernano and nanoceramic composites demonstrated lower roughness when different types of polishing techniques were used. Astropol (two-step) produce high surface roughness with all type of composite. Soflex with nanohybrid composite give higher surface roughness compared to other F&P systems.

Table 5.1: Mean Values and Standard Deviations of Surface Roughness (Ra, µm) of Resin Composites and Polishing Techniques				
Material	**Group**	**Mean**	**Std. Deviation**	**N**
Microhybrid	Fine diamond bur	0.253	0.003	**10**
	Astropol	0.254	0.002	**10**
	Soflex	0.254	0.003	**10**
	Control	0.257	0.004	**10**
	Total	0.254	0.003	**40**
Nanohybrid	Fine diamond bur	0.253	0.003	**10**
	Astropol	0.256	0.002	**10**
	Soflex	0.257	0.004	**10**
	Control	0.256	0.001	**10**
	Total	0.256	0.003	**40**
Supernano	Fine diamond bur	0.251	0.001	**10**
	Astropol	0.253	0.003	**10**
	Soflex	0.252	0.004	**10**
	Control	0.255	0.004	**10**
	Total	0.252	0.003	**40**
Nanoceram	Fine diamond bur	0.251	0.001	**10**
	Astropol	0.253	0.003	**10**
	Soflex	0.252	0.004	**10**
	Control	0.255	0.004	**10**
	Total	0.252	0.003	**40**
Total	Fine diamond bur	0.253	0.003	**40**
	Astropol	0.254	0.003	**40**
	Soflex	0.255	0.004	**40**
	Control	0.255	0.003	**40**
	Total	0.254	0.004	**160**

Table 5.2: Tests of Between-Subjects Effects on surface roughness.

Source	F	P value
Material	15.342	0.000
Polishing Techniques	15.568	0.000
Material * Polishing Techniques	1.099	0.365

General Liner model- Two-way ANOVA test was conducted; Sig. was set at 0.05

Table 5.3: Comparison of homogenous roughness subsets of the Tested Resin Composite Materials and Polishing Techniques.

	Means for groups in homogeneous subsets			Means for groups in homogeneous subsets		
Materials	1	2	Groups	1	2	3
Microhybrid	.2529137		Control	.2522692		
Nano-hybrid	.2529137		Bur		.2540317	
Super-nano		.2547895	Astropol		.2543465	
Nanoceramic		.2560204	soflex			.2560569
Sig.	1.000	.124	Sig.	1.000	.943	1.000

Turkey test was used.

Table 5.4 **Descriptive statistics for surface roughness among study sample and it is subgroups**

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Bur	40	.2531460	.00289174	.00043107	.2522772	.2540148	.24780	.25850
Astropol	40	.2543367	.00335238	.00049974	.2533295	.2553438	.24400	.25920
Soflex	40	.2554178	.00379625	.00056591	.2542773	.2565583	.24890	.26530
Control	40	.2553444	.00342056	.00057009	.2541871	.2565018	.24900	.26520
Total	160	.2545200	.00347533	.00026577	.2539954	.2550446	.24400	.26530

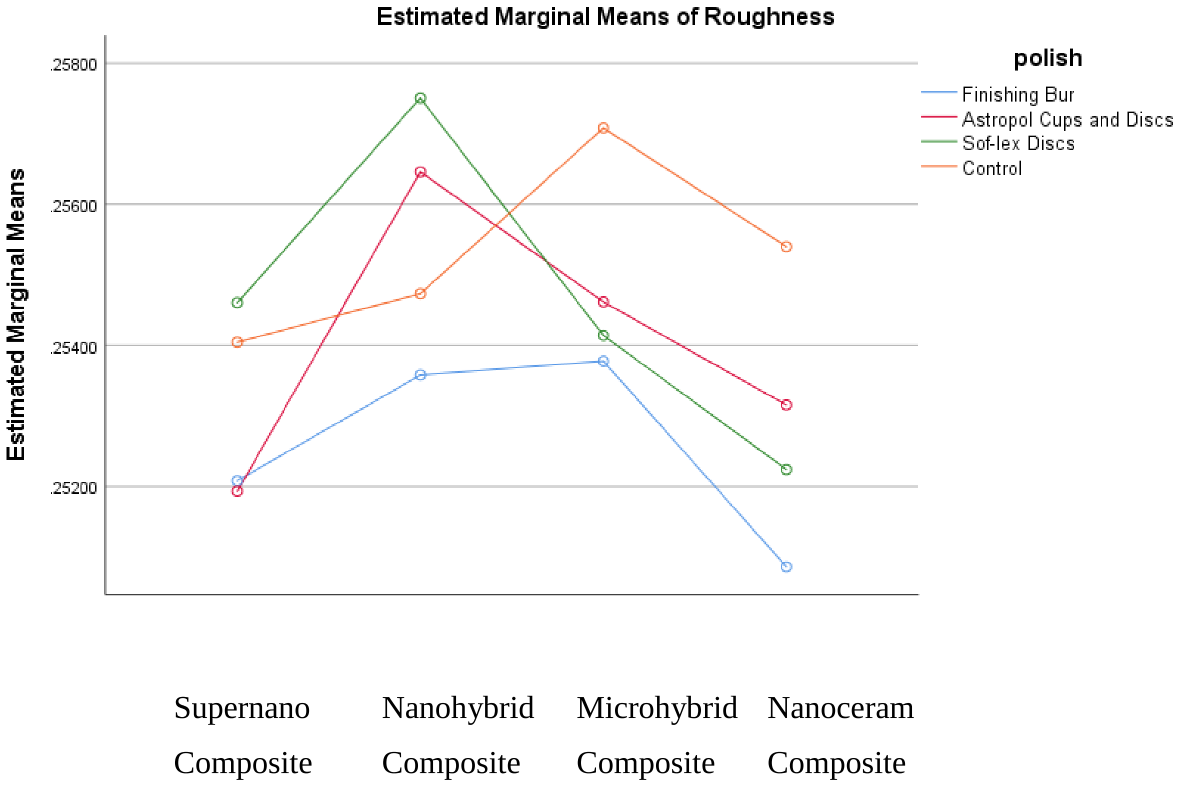

Figure 5.1: The homogenous distribution of group by surface roughness.

5.2 Microhardness:

Table 5.5 shows the distribution of average microhardness scores according to the type of composite and polishing techniques. It is clear that **Microhybrid composite** has the **highest average value** for microhardness (75.29±2.56) compared to other types of composites and the total microhardness of the study samples (74.71±1.69). Table 5.6 shows the statics of two-way ANOVA test which compared the **microhardness by materials, groups and both materials and groups**. Comparison of microhardness by materials showed significant differences (p=0.009). The differences observed between Microhybrid composite and Nanohybrid as well as Supernano composites. The nanoceramic composite showed no significant difference with other composites. No statistically significant differences between polishing technique were observed (p=0.417) (Table 5.7). Polishing with Bur and soflex discs demonstrated the lowest hardness with supernano and nanohybrid composites, respectively, compared to other types of composites and polishing techniques. Astropol showed higher microhardness with nanohybrid and nanoceramic composites.

Table 5.6 Comparisons of polishing techniques when used with different types of composites demonstrated statistically significant differences (p=0.001)

Table 5.5: Mean Microhardness Values (VHN kg/mm2) of the Tested Resin Composite Materials and Polishing Techniques

Material	Group	Polishing Techniques	Std. Deviation	N
Microhybrid	Fine diamond bur	75.89	3.19	10
	Astropol	73.67	2.02	10
	soflex	76.61	2.74	10
	Control	74.98	1.26	10
	Total	75.29	2.56	40
Nanohybrid	Fine diamond bur	73.99	0.83	10
	Astropol	74.84	2.11	10
	soflex	73.60	0.68	10
	Control	74.24	0.75	10
	Total	74.16	1.33	40
Nanoceramic	Fine diamond bur	74.02	0.77	10
	Astropol	75.15	0.86	10
	soflex	74.61	1.38	10
	Control	74.86	1.56	10
	Total	74.66	1.22	40
Supernano	Fine diamond bur	73.40	0.43	10
	Astropol	74.55	1.14	10
	soflex	74.07	0.58	10
	Control	75.13	0.95	10
	Total	74.29	1.02	40
Total	Fine diamond bur	74.32	1.89	40
	Astropol	74.55	1.66	40
	soflex	74.72	1.93	40
	Control	74.86	1.17	40
	Total	74.71	1.69	160

Table 5.6: Tests of Between-Subjects Effects on Microhardness

Source	F	P value
Material	1307.703	.009
Polishing Techniques	1264.519	.0541
Material * Polishing Techniques	1401.940	.001

General Liner model- Two-way ANOVA test was conducted; Sig. was set at 0.05

Table 5.7: Comparison of homogenous microhardness subsets of the Tested Resin Composite Materials and Polishing Techniques.

Materials	Means for groups in homogeneous subsets		**Polishing Techniques**	Means for groups in homogeneous subsets
	1	**2**		**1**
Nanohybrid	74.1585269		Control	74.3248025
Super-nano	74.2860352		Bur	74.5503135
nanoceramic	74.6607443	74.6607443	Astropol	74.7204713
microhybrid		75.2862588	Soflex	74.8668058
P value	.485	.289	P value	.417

Turkey HSD test was used; Sig. was set at 0.05

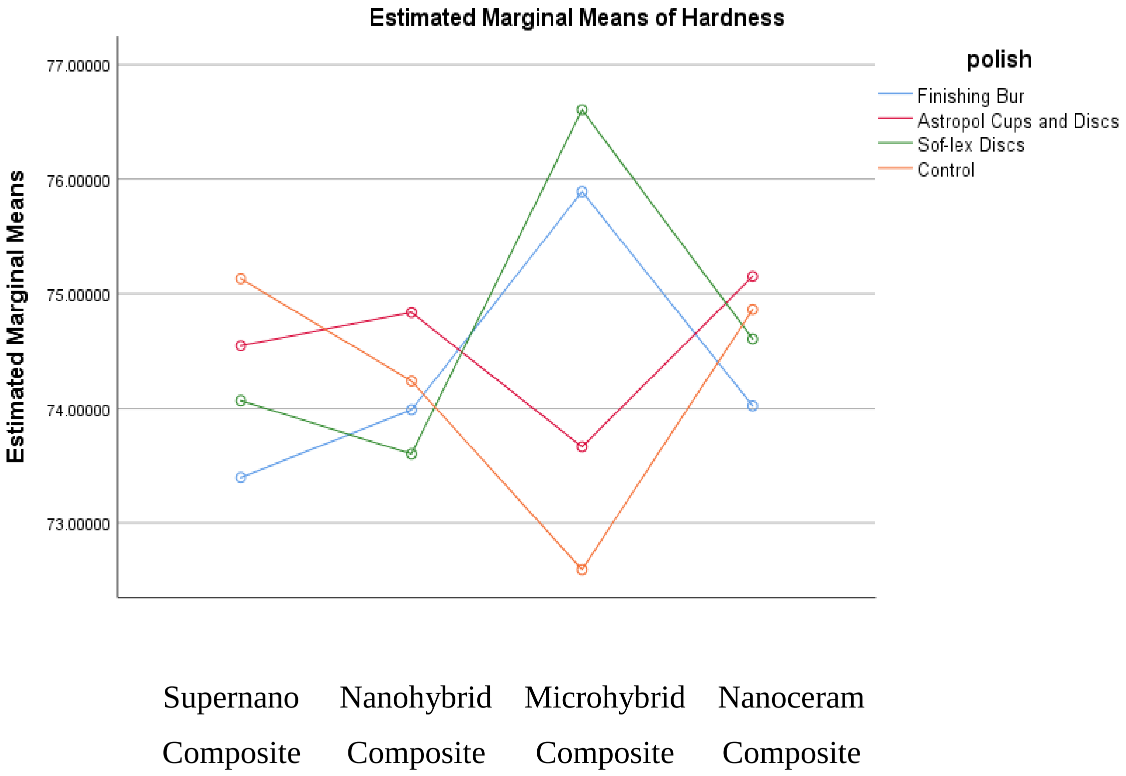

Figure 5.2: The homogenous distribution of group by microhardness.

Chapter 6

DISCUSSION

Discussion

The use of composite resin materials as tooth colored restoration has expanded considerably in recent years (Eltahlah et al., 2018). Ability to create anatomically accurate restorations that replicate the dental hard tissues is critical to the successful usage of these materials. When it comes to commercial resin composite restorative materials, clinicians are typically faced with a multitude of options. Many factors influence selection, including physical qualities and clinical performance, however surface finish is a significant aspect that can affect aesthetics and dental function (Wheeler et al., 2020).

Excellent finishing and polishing are critical steps in improving the esthetics and lifespan of composite restorations. The surface roughness of resin composite materials is the results of the combination of various factors, intrinsic factors such as material parameters as filler type, shape, and size and particles distribution. The type of polishing system and light curing process are extrinsic factors (llie & Hickel., 2011).

A rough surface detracts from the restoration's aesthetics, making it more prone to exterior stains and limiting the amount of gloss, which reduces the restoration's ability to reflect light. This, in turn, changes the composite resin's perceived color, resulting in a loss of aesthetics owing to stains (Petersen et al., 2020). Improper finishing and polishing processes might jeopardize the clinical performance of the restoration, lead to higher wear rates and susceptibility to plaque accumulation and hence clinical adherence of dental biofilm is expected. (Liebermann et al., 2019). This has been shown to have a direct influence on periodontal health and can result in gingival recession and localized inflammation (Wheeler et al., 2020). Plaque buildup worsens periodontal tissue inflammation and shortens clinical survival time (Habib et al., 2020). Many studies have shown that unpolished/rough surfaces, including as resin-based composites, ceramics, implant abutments, and denture bases, can accumulate more dental biofilm than polished surfaces (Yap., 2004).

In the current study, the surface roughness and microhardness of four resin composite restorative materials were investigated. The surface roughness and hardness were evaluated after finishing and polishing procedures using three finishing and polishing protocols. The mechanical properties investigated in this study, as surface roughness and microhardness of the resin composites are found to be affected by finishing and polishing systems. Regarding to this study, it was denoted that the type of resin composite did not show significant effect on the polishing technique since P value was 0.365) Table 5.2. At the present study, four types of resin composites shade A2 were examined, namely: microhybrid composite (Dynamic plus), nano-hybrid composite (***Nexcomp***), super-nano (ESTELITE Σ QUICK) and nanoceramic composite (ZENIT). The selections of these four resin composite materials were based on different in their composition, preferred by most of the dentists, can be used at anterior and posterior teeth and available in the local market. Three finishing and polishing systems were used in this study namely; Fine diamond Finishing bur, Sof-Lex discs (3M-ESPE, Dental Products, St Paul, MN USA) and Astropol® cups and discs (Ivoclar Vivadent, Amherst, NY, USA). Different finishing and polishing systems were investigated in this study because they are routinely used at the dental clinic in the local area. The specimens were prepared in laboratory in Cairo-Egypt. The specimens were fabricated to a specific dimension to standardize the specimen dimension for the four types of resin composites.

Results of this study showed that surface roughness of microhybrid and nanohybrid composite was homogenous and higher than other types of composite. These findings could be attributed to the chemical composition of these resin composites and the type of finishing and polishing systems used. As it explained by Guler et al., who stated that the type of resin composite used has an effect on how the surface is smooth as type, shape, size, and distribution of the fillers, as well as the organic matrix and its interface, all play a role as well as the techniques for finishing and polishing (Guler et al., 2018).

Due to the fact that the resin matrix is generally soft, while the filler particles are quite hard, the identical techniques for polishing provide various polishing outcomes depending on the type of resin composite used (Kumari et al., 2019). In addition , factors such as particle size, polishing system type, and degree of polymerization have a crucial influence (Tjan & Chan., 1989).

Filler particles only usually depleted away when the surrounding resin wears away according to Wheeler et al., research (Wheeler et al., 2020). As a result, author concluded that increasing the hardness of resin rather than filler particles is preferable for producing uniform polishing.

The goal of the pre-polishing step was to establish a consistent baseline from which to start polishing, to simulate clinical conditions, and to well focus on the polishing system's effect. Regarding using diamond bur researchers found that the mean surface roughness of composite resins has been demonstrated to vary depending on the polishing bur employed. A recent research reporting that the mean surface roughness of a microhybrid composite resin finished with bur was between (2.82m-0.26m) (Daud et al., 2018). These results were consistent with the current results where the surface roughness of microhybrid composite finished and polished with diamond bur is 0.253.

Smoothness is essential for both functional and aesthetic considerations. A well-polished restoration would often have a shiny and smooth surface (Lassila et al., 2020). Clinically, determining the finishing sequence that allows for the creation of the smoothest surface with the fewest instruments and the least amount of time is critical and desired (Nair et al., 2016). In this study the surface roughness and microhardness were examined using fine diamond bur as one-step procedure, Astropol as two-steps and soflex as four-steps finishing and polishing systems. The obtained results showed that the one-step systems resulted in lower surface roughness than the other types of finishing and polishing systems.

Surface roughness may be measured using both qualitative and quantitative methods as an indicator of finishing and polishing efficacy (Kumari et al., 2016). Moreover, surface roughness of composite resins can be measured using a variety of techniques, including optical and scanning electron microscopy, contact profilometry, laser noncontact profilometry, and the atomic force microscope (Ereifej et al., 2013; Kumari et al., 2016). In this in vitro study optical profilometer was used to investigate and compare the surface roughness (Ra) of various composites polished with different brands of finishing and polishing systems and Vickers hardness test was used to measure microhardness.

The highest mean Ra value obtained for all composite materials tested in the current study was 0.2575 µm, which was produced by Nanohybrid composite finished and polished with soflex system. The above results were in accordance with another study done by Yasser Alfawaz in 2017 who found that the mean surface roughness value of nanocomposite after using soflex discs was significantly higher roughness values compared with other types of finishing and polishing systems (Alfawaz., 2017).

It has been reported that restoration with roughness value of less than 1µm appeared optically smooth (Nasoohi et al., 2017).

In the current study, among the finished and polished systems, the smoother surfaces were seen in specimens F&P with the one step F&P systems which was the fine diamond bur compared with specimens F&P with Astropol and soflex F&P systems. The mean roughness value obtained when using fine diamond bur in this study among all types of composite was ranging from 0.251-0.253µm. However, both Supernano and Nanoceram composites produced the lowest surface roughness among all other composites when they finished with fine diamond bur one-step F&P procedure. Both composites obtained similar roughness value, 0,251µm.

our results were in accordance with the study done by Atabek et al., who examined the effect of several polishing systems on the surface roughness of Nanoceram and nanofilled resin composites. The authors found that the nanoceram composites produced the smoothest surface with one-step finishing and polishing system. Our findings revealed that supernano and nanoceram produced smoother surface finish (lower roughness values) than microhybrid and nanohybrid these results were in line with their study (Atabek et al., 2016).

In the clinical practice, it is mostly necessary to use diamond or carbide burs to contour anatomically structured and concave surface (Ozgunaltay et al., 2003). The final goal from finishing and polishing procedures is to create the ideal anatomical features, a balanced occlusion, and a reduction in roughness, gouges, and scratches from the preparation process (Gupta et al., 2012). The findings of the current study revealed that different finishing and polishing techniques have a significant effect on the surface roughness and microhardness of the resin composite. Considering the reduced number of steps, the current one-step finishing and polishing system may be preferable for polishing resin composite restorations.

Among all types of resin composites an increase in the surface roughness values were observed in the control group treated with sandpaper only without finishing and polishing procedure. When the composite surfaces covered with celluloid strip, this top layer considered resin-rich layer and would make the restoration surface unstable. This resin-rich surface should be removed since it can wear easily in the oral environment, and stained by colored foods and drinks. This is the reason for removal the top layer of the composite specimens with sandpaper. The higher roughness value for all types of composite was for the control group. Though the sandpaper was used for gross reduction and to produce flat surface this high value may be related to the fact that, to mimic the clinical condition, the resin rich layer is removed upon complete the restoration and before finishing and polishing procedure.

Regarding the use of the two step finishing and polishing system in the current study, these F&P systems contain aluminum oxide grits, which are F (45µm) and P (1µm) as claimed by manufacture. The main advantages of this approach is that, these systems produced equivalent surface smoothness on resin composites in half the time as four-step systems.

The hardness of aluminum oxide is significantly higher than silicon dioxide generally, higher than most filler materials used in composite formulations. The trend of soflex discs is to provide a slightly smoother surface with the aluminum oxide an abrasive on rigid matrix as this can flatten the filler particles and abrade the softer resin matrix at an equal rate (Kumari et al., 2019).

Our results revealed that the two; and four- step systems evaluated behaved similarly when surface roughness were analyzed, except for the nanohybrid composite, in which soflex four-step polishing systems produced a higher surface roughness. There are a few possible explanations for the higher surface roughness of nanohybrid composite when finished with soflex F&P systems. The first is the larger and irregular filler size. Larger and irregular filler size was obtained by grinding larger particles and causing a lot of space between fillers, for that the manufacturers added nanomer and nanocluster inside to fill the space. The larger filler would protrude from the surface during curing. It has been reported, pressure would gather more on the irregular filler and increase the chance of the filler detaching from the resin surface. When the larger filler detached from the matrix, it would create a larger hole on the surface and increase surface roughness. Another possible explanation for higher surface roughness is that the nanomer and nanocluster would detch along with the softer matrix during polishing. This would increase roughness (Patel et al., 2016). In the current study, nanohybrid composite exhibited the roughest surfaces (the highest Ra values) which is similar to other researchers (Kumari et al., 2016).

Despite the fact that the finishing discs for the two systems have different compositions (i.e., Astropol has silicon carbide abrasive and soflex has aluminum oxide), the abrasive particles in both systems are nearly the same in size and composition. As a result, it's not surprise that these systems produce identical outcomes.

The sof-lex discs (aluminum oxide disks), have been developed as a four steps polishing systems. In the present study, soflex showed lower roughness value than the Astropol polishing systems with microhybrid and nanoceram composite. This result was obtained possibly due to coarser abrasive particles in the Astropol systems than in other systems (Hassan et al., 2015).

The effectiveness of the polishing system depends on the hardness of the cutting particles and materials. In addition, the production of a smooth surface may also depend on ability to abrade filler particles and organic matrix at an equal rate without dislodging the filler particles and gouging into the material (Kumari et al., 2019; Nair et al., 2016). This is because the hardness of the aluminum oxide impregnated discs of Sof-Lex is higher than most filler particles in resin composites. Our result are in contrast with Antonson et al., 2011 Who found that Sof-Lex achieved the lowest roughness value among the other finishing and polishing systems utilized in their study(Antonson et al., 2011). However, Jung in 2002 mentioned that the usage of Sof-Lex system is limited to accessible convex surfaces. Hence, other finishing systems could be utilized to construct complex occlusal anatomy or concave surfaces (Jung., 2002) In another study done by Mitra et al., in 2013 they supported the homogeneous abrasion concept of the (Sof-Lex) aluminum oxide discs. Because the fillers in the composite were so small that their stiffness was reduced, their flexibility promoted a homogeneous abrasion of the fillers and the resin matrix (Mitra et al., 2003).

Our results are in agreement with Buchgraber et al., 2010 who found that the sof-lex fine and superfine discs produced smoother surface than pogo finished and polishing system. The auothers added that there was significant difference in roughness between Nanofill and other types of composites. The Nanofill composite produce the smoothest surface(Buchgraber et al., 2011). This is similar to the results obtained in the present study where the soflex produced smoother surfaces than Astropol polishing systems with some types of composite. However, the type of composite did not show significant effect on polishing technique (P=0.365).

The explanation for this could be related to the compositional nature of the soflex discs and the Astropol systems. As suggested by, Abzal., et al The aluminum oxide integrated in Sof-Lex discs had a superior finishing surface and were less roughness than diamond abrasive particles in Astropol, despite the latter's good surface finish. The fundamental reason for this is that the Sof-Lex discs do not displace composite filler particles like the less flexible Astropol points do. Aluminum oxide in the Sof-Lex discs causes homogeneous abrasion of the fillers and resin matrix. Furthermore, the Sof-Lex discs adapts well to the composite resin's surface (Abzal et al., 2016).

Ozgunaltay et al., examined the effects of several polishing systems on the surface roughness of nano-ceramic and nano-filled composite resins using scanning electron microscope and profilometers. The auothers found that nanoceramic composites produced smoothest surface with enhance finishing system the (two step) and pogo (one step), and the polishing systems produced clinically acceptable surface roughness on the tested composite (Ozgunaltay et al., 2003). For that reasons the differences in surface roughness after finishing and polishing between the systems could be attributed. to the different shapes of particle size and their arrangement within the resin matrix. It has been reported that Aluminum oxide disks are of limited use because of their shape, which make them difficult to use efficiently, mainly in the posterior region of the mouth (Uçtaşli et al., 2007; Abzal et al., 2016).

Furthermore, in agreement with this current study veena kumara et al., examined the effect of polishing procedures such as soflex discs polishing system and Politip and Opti-disc on the surface roughness and microhardness of composite resin restorative materials. The surface roughness was measured with optical profilometer and atomic force microscopy. Their results revealed that the soflex polishing system showed better polishing ability in both groups of tested composite universal submicron hybrid composite, nanofilled composite (filtek Z350 XT) than Politip and optidisc(Kumari et al., 2019). Their results were similar to our findings where the soflex finishing and polishing system showed smoother surface than Astropol and control group. However, results of our study found that the Astropol (2-step systems) and soflex (4-step systems) are homogenous and more comparable among each type of composite.

Moreover, the average roughness in microhybrid and nanohybrid composite was homogenous and higher than other types of composites. These results are consistent with the microhardness value of the microhybrid composite as it produced the highest average value for microhardness in particular with soflex polishing discs (76.61+2.74). By comparing roughness values obtained with different polishing systems, it can be clearly observed that the one-step polishing systems produced lower roughness than other type, it means smooth surface finish. In addition, for most resin composites investigated in this study the four-step soflex polishing disc resulted in a significantly lower surface roughness followed by Astropol. These results are consistent with Dhananjaya et al., in 2019 who reported that soflex polishing systems produce lower roughness than Astropol polishing system (Dhananjaya et al., 2019). Hardness and type of the abrasive, and the geometry of the instruments employed for F&P systems can explain these differences in results (Marigo et al., 2001).

Recently in another study done by Aljamhan et al in 2021., Conducted a study to compare the effect of three finishing/polishing systems on the surface roughness (Ra) of resin composites. In their study they used (Astropol®, PoGo®, Sof-Lex®, 3M ESPE). They found statistically significant differences ($P < 0.05$) between the Ra values of all composite materials tested. Astropol® produced the highest Ra value, and the microhybrid composite exhibited the lowest surface roughness (Aljamhan et al., 2021). Their results were not in line with the current study, where microhybrid composite had the higher surface roughness.

Although different polishing procedures produce different surface roughness values for the composites, all F&P systems attained values between 0.251-0.257mm for all composites.

Microhardness is defined as resistance of material to indentation and is an important mechanical property that predicat the polymerization degree of cure of restorative materials (Eden et al., 2012). In this study, the mean VHN measured immediately after finishing and polishing systems with sandpaper was ranged from 74.24 to 75.13 this higher range may be related to fact that polishing with abrasive sandpaper was performed to mimic the clinical conditions in which it responsible for removal of surface rich-layer in organic matrix.

The materials microhardness is one of the most important properties, which correlates with resistance to intra-oral softening, compressive strength and degree of conversion (Vltarelli et al., 2010). In the present study, it was found that the microhybrid composite finished with soflex discs showed the highest microhardness value followed by the diamond bur then the control group and the lower value of surface microhardness was obtained with Astropol F&P system. The increase in hardness of microhybrid composite may be attributed to reduce in surface roughness of this composite. It might be expected that there is relation between the surface roughness and microhardness, as lower surface roughness resulted in higher hardness. Our results, found that the nanohybrid composite obtained higher surface roughness when finished with soflex polishing systems and produced lower microhardness value.

In current study nanoceramic composite have a high value of microhardness in particular when finished with Astropol F&P systems compared with other F&P systems. In addition, the lowest microhardness was obtained with Supernano composite when finished with diamond bur. These values are corresponding to the lower values of surface roughness obtained for these two composites and the F&P systems.

The obtained results could be due to several factors determining microhardness included; composite properties such as type of organic matrix, size, distribution of loading particles and factor related to abrasive systems such as flexibility of the material in which the abrasive impregnated, hardness of the abrasive, size and shape, speed and shape of application of the instruments used (Kumari et al., 2019).

The highest hardness value after finishing and polishing was observed in the microhybrid composite (76.61), and the lowest hardness value was observed in the Supranano composite (73.40).

The different microhardness values obtained for these different types of composites could be related to the difference in their filler/resin ratio and hydrolytic breakdown of the silane/filler particle bond, it has been documented that filler particles dislodge from the outer surface of the material causing surface roughness and decrease in hardness. In addition, authors stated that the microhardness value deepened on the degree of conversion and the type of the filler (soderholm et al., 1984). The variance values were obtained from different studies that evaluated surface roughness and microhardness. These results should be interpreted with caution since in clinical practice; the use of the restorative materials and polishing systems may be limited to the accessibility and flatness of the surface to be finished, as most of the newest polishing systems are disk shaped.

Chapter 7

CONCLUSIONS & RECOMMENDATIONS

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS:

According to research methodology used and within the limitations of the present in vitro study, it was concluded that:

1. The type of resin-composite and the polishing technique used are important factors affecting the surface roughness and surface microhardness.
2. All polishing systems produced clinically acceptable surface roughness results among all the tested composite materials.
3. The smoothest surfaces finish was obtained when using fine finishing bur particular with supernano and nanoceramic composites.
4. Microhybrid and nanohybrid composites were comparable and showed higher surface roughness than other types of composites.
5. Nanohybrid composite showed higher surface roughness and lower microhardness than other type of composites when finished with Soflex discs F&P systems.
6. Microhybrid composite obtained high roughness and low microhardness with Astropol F&P systems.
7. Soflex and Astropol F&P systems were homogenous and comparable but soflex showed better polishing ability for all type of composite.
8. The microhybrid composite has the highest surface hardness in particular when finished with soflex F&P system.
9. The effect of finishing and polishing systems on the surface roughness and microhardness is dependent on both the polishing systems and the restorative materials.

7.2 Recommendations:

1. Further studies are required to evaluate the effect of finishing and polishing systems on the surface roughness and microhardness of the resin composite restorations using other types of composites and F&P systems

2. Further clinical studies are needed to compare the effect of different finishing and polishing systems on surface roughness and microhardness of composite resin restorative materials.

3. Further studies are required on convex and concave tooth surfaces there to better investigate how these resins composite and polishing systems will perform under clinical conditions.

4. Further studies are needed to determine the most appropriate finishing technique in clinical practice when access is limited and restoration surfaces are not flat.

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THESIS PROPOSAL

Evaluation of the Surface Roughness and Microhardness of Resin Composite Restorative Materials after Different Finishing and Polishing Procedures

(An in vitro study)

تقييم خشونة السطح والصلابة الدقيقة لمواد الحشوات الضوئية المركبة بالراتنج بعد عمليات التشطيب والتلميع المختلفة (دراسة في المختبر)

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Proposal

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1. INTRODUCTION

Now days, resin composites become one of the most investigated material in dentistry. Patients and clinicians prefer these material because of their excellent esthetic, moderate cost compared to ceramics and adhesion to tooth structure.[1] With the development of composites, one of the desirable features for a satisfactory and esthetic restoration is smooth surface finish.[2] Finishing and polishing are measures undertaken in the restorative procedure to obtain a smooth, shiny surface of a restoration, keeping in mind esthetics and maintenance of periodontal tissues in healthy condition. Finishing procedure means a gross contouring or reduction of excess-filled restoration to achieve an ideal anatomy, whereas polishing means that removal of the roughness and scratches created by the finishing devices.[3 4] Optimal finishing and polishing are important clinical steps in restorative dentistry that influence both esthetics and longevity of restorations.[3] Improper finishing and polishing of dental restorations can result in surface roughness which is subsequently associated with excessive gingival irritation, plaque accumulation, more surface staining, and poor esthetics of restored teeth that may in turn lead to enamel demineralization, recurrent dental caries, as well as periodontal problem.[5] It has been documented that change of surface roughness in the order of 0.3 mm can be detected by the tip of the patient tongue that may cause problems in quality of the entire work.[6]

Ideally the finishing and polishing procedures should be delayed at least 10-15 minutes following the final phase of light curing procedure so as to permit some dark polymerization to take place.[3] Delaying the time of the finishing and polishing procedures make the restoration less suscebitiple to negative effect produced by heat generation.[7, 8]

Microhardness is defined as resistance of the material to indentation and is an important mechanical property that predicts the polymerization degree and depth of cure of restorative materials.[1] Microhardness is essential to the material in resisting masticatory forces, increase wear resistance and providing greater longevity of the restoration. When microhardness of the composite reduces, the material become more susceptible to scratches which cause bacterial adhesion, discoloration and failure of the restoration.[7] Therefore the surface microhardness of composite resin should not be changed after restoration in mouth.[12]

A wide variety of instruments and materials are commercially available and used by dental clinicians for finishing and polishing procedures such as abrasive systems include aluminum oxide (AL_2O_3), carbide compounds, diamond abrasives, silicon dioxide, zirconium oxide and zirconium silicate and polishing instruments that include coated abrasive discs and stripes, stones, aluminum oxide or diamond pasts, soft or hard rubber cups or points, and wheels or brushes impregnated with abrasive.[9] All these instruments and systems available as one-, two-, three- and four-step finishing and polishing system. The effectiveness of the polishing system depends on the hardness of the cutting particles and materials, and the production of smooth surface depends on the ability to cut the filler particles and organic matrix of the resin composites.[10]

In the recent years, resin composites have rapidly evolved in terms of filler particles and resin matrix composition and structure.[11] The application of Nano, bulk-fill, fiber-reinforcement and ion-releasing technologies in the dental materials field has resulted in the development of new resin composite containing different size and shape particles.[11-13] Resin composites are heterogeneous materials contains a mixture of resin matrix mainly a dimethacrylate, reinforcing filler typically made of radiopaque glass, and a silane coupling agent is to bond the filler to the matrix and chemicals that influence polymerization reaction.[14, 22] With improvement of the composite the significant development was the Nanocomposites that consist of nanomers (5nm to 75nm particles) and nanocluster agglomerate fillers (0.6 µm to 1.4 µm). Nanocomposites and universal submicron hybrid composites demonstrate mechanical and physical properties similar to those of hybrid composites along with excellent esthetic characteristics of microfill composites and superior polishability and gloss surface restorations.[14, 15]

Different instruments and procedures can be used for finishing and polishing of resin composite restorations, and the effects of these instruments and procedures on different types of composites have been widely investigated, and the results were varied.[10, 11, 16-21] It has been documented that nanofilled composite showed superior polishability than the microfilled composite and Filtek Z250-hybrid composite when comparing different finishing and polishing systems. The hybrid composite showed the least polishability compared with microfilled and nanofilled composites, and the Enhance polishing system showed the least polishability among all the polishing systems used.[18]

In addition, the Sof-Lex Pop-on system was found to produce smoother surface than Enhance polishing system.[19] Large particles embedded in Sof-Lex disks tend to rip through the surface of the composites and when used with certain hybrid composites tend to cut and abrade filler particles and resin matrix equally, resulting in smoother surface.[19] However, some researches showed that, the polishing protocol was significant, and stronger factor than the type of composite material,[22] and reported that there is correlation between surface gloss and surface roughness. The lower surface roughness the higher surface gloss, [6, 23] and the surface gloss improved consistently during the polishing procedures.[6] Additional factors can affect the polishing results, including the amount of pressure utilized while polishing, the orientation of the abrading surface and the amount of time spent both with each abrading surface and abrasive material should be considered for evaluating the clinical efficiency among the polishing systems available today.[24] The discrepancy between the size of abrasive particles present in the abrasive discs and abraded material should be minimal to reduce the creation of scratches or roughs on the polished surface.[25]

Transparent matrices such as Mylar stripe are preferred to produce smooth surface finish with highest gloss, but it is difficult to achieve proper anatomical contour of the restoration with Mylar strip.[26] In this circumstance, it has been found that the lowest surface roughness was found in the sample that in contact with matrix stripes, were lower than threshold mean roughness (Ra) value of 0.2 mm.[26, 27] Furthermore, authors found that, the Soflex spiral wheel had the least roughness value, which promote homogenous abrasion of fillers and resin matrix.[27] The trend of sof-lex discs is to provide a slightly smoother surface with aluminum oxide abrasive on rigid matrix as this can flatten the filler particles and abrade the softer resin matrix at an equal rate.[28] Limited use of aluminum oxide discs is because of their shape, which makes them difficult to use efficiently, particularly in the posterior regions of the mouth. Soflex spiral wheels have unique, flexible shape which easily to adapts to irregular, convex and concave tooth surfaces and is effective from any angle. The unique shape of soflex spiral wheel is an advantage over soflex discs in adapting to tooth structure.[27]

High quality finishing and polishing of dental restorations are important aspects of clinical restorative procedures, and it is essential to determine which finishing and polishing system offer the best results. In addition, there is no certain agreement and harmony on which finishing and polishing material and technique provides the smoothest surface for resin composite, especially with the increase launch of new finishing and polishing products in the market.

2. AIM OF THE STUDY

The aim of this in-vitro study is to evaluate the surface roughness and microhardness of four resin composite restorative materials after applying three different finishing and polishing procedures.

3. MATERIALS AND METHODS

3.1 MATERIALS:

Material used in this study are four commercial available resin composites restorative materials and three different finishing and polishing procedures. The four resin composites were chosen because of differences in their particle sizes, and loading in addition to the availability in the market and used by local dental practitioners. The three finishing and polishing systems were selected because they possess different composition and number of finishing and polishing steps.

The four resin composites are:

1- Microhybrid composite.
2- Nanohybrid composite.
3- Supranano composite.
4- Nanoceram composite.

The three finishing and polishing instruments are:

1- Finishing bur (diamond finishing bur)

2- Enhance flex two-step system NST-EF (aluminum oxide and diamond – silica).
3- Sof-lex discs four-step system (aluminum oxide)

3.2 METHODS:

3.2.1. Specimen preparation:

160 disc-shaped specimens of 10 mm in diameter and 2 mm in thickness will be fabricated from the four resin composites restorative materials of shade A2. A silicon mold will be used for fabrication of the specimens. The molds will be filled with resin composite, then a Mylar strip is placed over the top of the composite then a glass slide of 1-2 mm thickness is positioned on the strip. Excess material will be removed using explorer followed by compaction of resin. Each specimen will be light cured using one light-curing unite positioned in direct contact with the Mylar stripes. The light output of the light curing unite will be frequently checked with radiometer. The cured specimens will be then stored in dark and 100% humid environment at 37c for 24 hours prior to finishing and polishing procedures.[20, 27]

3.2.2 Specimens grouping:

Details of number and distribution of the testing groups are illustrated in Figure 1. A total number of 160 specimens will be divided into four equal groups according to the type of resin composite (group 1, 2, 3, 4). Each type of composite will contain 40 disc-shaped specimens as follow:

Group (1): Microhybrid composite (n=40)

Group (2): Nanohybrid composite (n=40)

Group (3): Supernano composite (n=40)

Group (4): Nanoceram composite (n=40)

Each type of resin composite (each group of composite:1 to 4) will be further divide into four sub-groups (A, B, C, D) based on the type of finishing and polishing procedure. Each sub-group consisting of 10 specimens as follow:

Group A: (n=10) Mylar strip: no procedure, (Control group).

Group B: (n=10) Diamond finishing bur - The cured specimens with the Mylar strip is subjected to finishing procedure using diamond finishing bur

Group C: (n=10) Procedures in **Group B** followed by two-step finishing and polishing system -Enhance system.

Group D: (n=10) Procedures in **Group B** followed by four-step finishing and polishing system- Sof-lex discs, aluminum oxide-impregnated discs

3.2.3 Finishing and polishing procedure:

Group A; is the control group (Mylar strip). Specimens in this group receive no finishing and polishing treatment. **Group B;** immediately after the light-curing cycle, the specimens were taken from the mold and were initially finished with diamond finishing bur with light hand pressure, under water coolant using a planar motion for 30 seconds using a low-speed hand piece, [21, 27] removing the initial shiny surface caused by curing against the mylar strip and thus simulating a clinical finishing procedure. **Group C**; procedure in group B followed by two-step Enhance-flex system. In step 1: application of medium-grit, and in step 2: application of fine-grit. **Group D**; procedure in Group B followed by using four-step soflex disc system with coarse, medium, fine, and superfine aluminum oxide-impregnated disks, sequentially. The finishing and polishing procedures will have contained repetitive strokes with water coolant to prevent heat generation and formation of grooves. After completion the finishing and polishing procedure all the specimen will be wash and dry and then stored in 100% humid environment at 37c for 24hours prior to measuring their surface roughness and the microhardness.[21, 27]

3.2.4 Surface roughness Evaluation:

Optical Profilometer will be used for measurement of the surface roughness (Ra) of all specimens. The surface roughness will be measured three times for each specimen. i.e. surface roughness readings will be recorded three times on three different locations. The Ra value was recorded as the average of these three readings. The optical profilometer show three dimensional topography of the specimens.

3.2.5 Microhardness Evaluation:

Microhardness measurements on cured surfaces of all specimens will be determined by Vicker's Hardness Testing Machine. The Vicker's surface microhardness test method consist of indenting the test specimen with a diamond tip, in the form of a right pyramid with a square base and Vicker's microhardness readings were undertaken using a load of 50 g for 20 s. Three indentations were recorded from each specimen that were equally spaced over a circle and not closer than 1 mm to adjacent indentations or the margin of the specimen, and the microhardness value was obtained as the average of these readings.

3.2.6 Statistical analysis:

All measurements data obtained will be collected, tabulated and statistically analyzed.

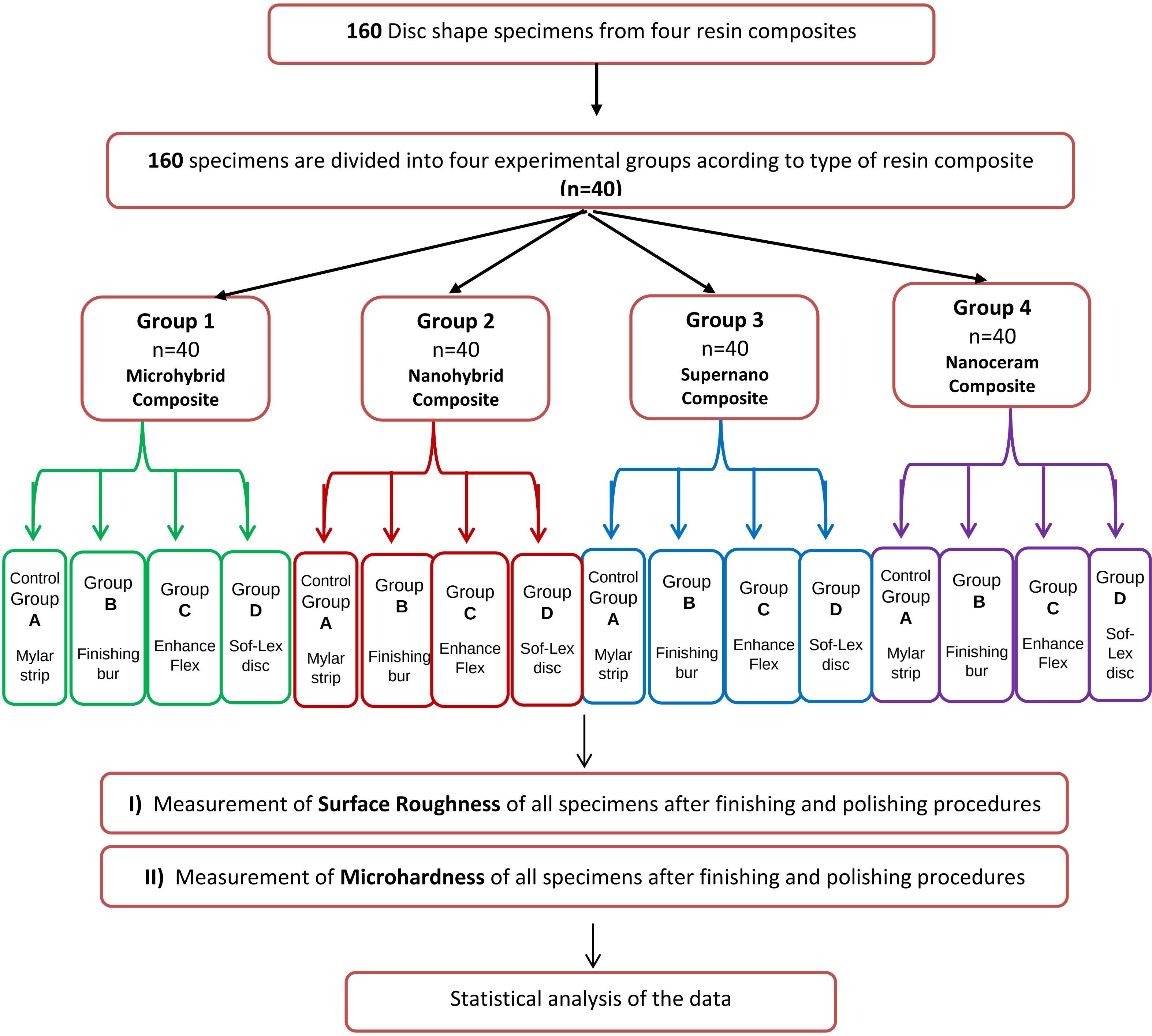

Figure 1: Flow chart illustrates number and distribution of the testing groups

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ملخص بالعربي

تأثير إجراءات التشطيب والتلميع على خشونة السطح والصلابة الدقيقة لمواد الترميم المكونة من الراتنج
(دراسة في المعمل)

قدمت من الطبيبة

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ملخص

هدف الدراسة: تقييم تأثير ثلاثة أنظمة مختلفة للتشطيب والتلميع (P&F)؛ البر الماسي الناعم وأقراص Sof-lex وأكواب وأقراص Astropol® على خشونة السطح والصلابة الدقيقة لأربعة مركبات من الراتنج.

المواد والطرق: تم تحضير 160 عينة على شكل قرص (10 مم × 2 مم) في قالب معدني باستخدام أربع مواد مركبة من الراتنج وتم تخزينها في ماء مقطر عند 37 درجة مئوية لمدة 24 ساعة. ثم قسمت العينات إلى أربع مجموعات تجريبية (ن = 40) حسب نوع مركب الراتنج. المجموعة 1: مركب Microhybrid (Dynamic Plus)، المجموعة 2: Nanohybrid (Nexcomp) ، المجموعة 3: مركب Supernano (ESTELITE Σ QUICK) ، والمجموعة 4: مركب Nanoceram (ZENIT). لكل نوع من أنواع الراتينج المركب، تم تقسيم العينات الأربعين إلى أربع مجموعات فرعية (A، B، C، D) بناءً على نوع إجراءات الصقل والتلميع على النحو التالي ؛ أ: ورق الصنفرة ، ب: بور الماس الناعم ج: أكواب وأقراص Astropol® (خطوتين) نظام P &F ، D: أقراص Sof-lex (أربع خطوات) نظام P&F. تم إجراء قياسات خشونة السطح لجميع العينات المركبة من الراتينج باستخدام مقياس ملف تعريف السطح الرقمي USB وتم تسجيل البيانات باستخدام برامج الكمبيوتر (Elcomaster 2، Elcometer Instruments). تم تحديد صلابة السطح الصغيرة للعينات باستخدام جهاز العرض الرقمي Vickers Micro-Hardness Tester. تم حساب القياسات وتحليل البيانات التي تم الحصول عليها إحصائيا باستخدام برنامج SPSS. تم تطبيق ANOVA أحادية الاتجاه وثنائية الاتجاه لتقييم الاختلافات المهمة بين المواد المركبة باستخدام أنظمة P&F مختلفة. تم استخدام اختبار Tukey اللاحق للمقارنات الزوجية بين الوسائل.

النتائج: تم العثور على اختلافات معنوية في خشونة السطح والصلابة الدقيقة وفقًا لنوع أنظمة P&F ومركبات الراتنج ($P < 0.05$). تم تسجيل أنعم قيمة السطح لمركب السيراميك النانوي. تم الحصول على أعلى قيمة للصلابة الدقيقة مع المركب الهجين الدقيق الذي تم الانتهاء منه باستخدام أقراص Soflex (أربع خطوات) أنظمة P&F.

الاستنتاجات: بناءً على النتائج التي تم الحصول عليها، يمكن الاستنتاج أن إجراء P&F يؤثر بشكل كبير على خشونة السطح والصلابة الدقيقة للمواد المركبة الراتنجية المختبرة. أظهر مركب Nanoceram و supernano أقل قيم خشونة السطح، بينما أظهر مركب nanohybrid أعلى قيمة لخشونة السطح بين المركبات المختبرة عند الانتهاء من نظام P&Soflex F. أظهر المركب الهجين الميكروي أعلى صلابة دقيقة.

الكلمات الدالة: مركبات الراتينج، نظام الصقل والتلميع، خشونة السطح، الصلادة الدقيقة.